THE LIBRARY OF USEFUL STORIES

THE STORY OF LIFE IN THE SEAS

BY

SYDNEY J. HICKSON

T. L. T Hankinson
Charleston Illinois.
March 18-1910

THE

LIBRARY OF USEFUL STORIES

THE ATLANTIC WALRUS (ODOBÆNUS ROSMARUS) OF THE ARCTIC REGION.

THE STORY OF LIFE IN THE SEAS

BY

SYDNEY J. HICKSON, D. Sc., F. R. S.
PROFESSOR OF ZOOLOGY IN THE OWENS COLLEGE, MANCHESTER

WITH FORTY-TWO ILLUSTRATIONS

NEW YORK
D. APPLETON AND COMPANY
1906

PREFACE.

THE story of the life of animals and plants in the sea is one with so many aspects, that it is difficult to choose the points that may be included, and those that may be omitted from a book intended for the general reader. To some the story of the food Fishes and the Whales is of the greatest interest; to others the beautiful shapes and colours of shells have a predominating fascination; and to those who have devoted themselves to geological study, the history of the animals that contribute to the formation of the reefs and the ocean-bed present features of special attraction. To many, then, the perusal of my book must lead to disappointment, as no one of these aspects has been treated adequately; but if some new interest is awakened, some new train of thought quickened into life, one of the objects I had in view will have been gained.

The book is only intended to be a sketch of some of the most important lines of scientific researches which are now being pursued by zoologists in many parts of the world. Discoveries, which are of the deepest interest to all intelligent minds, are in many cases described in books and periodicals that do not come within the reach of the general public. I have tried, therefore, to collect some of them into a small compass and describe them in language which I trust will be

intelligible to those who have not been trained in the alphabet of zoological technicalities. The use of some long words was unavoidable, but I have endeavoured to explain them adequately either in the text or in the index.

Some of the illustrations have been copied from the works of other Naturalists, and the sources from which they came are acknowledged in the list of illustrations; but the majority of them have been drawn, specially for this work, from specimens from the Manchester Museum or my own collections.

SYDNEY J. HICKSON.

November, 1897.

CONTENTS.

LIST OF ILLUSTRATIONS.

OUTLINE CLASSIFICATION OF ANIMALS MENTIONED IN THIS BOOK.

PROTOZOA		Foraminifers. Radiolarians.
PORIFERA		Sponges.
CŒLENTERATA		Sea-anemones. Corals. Jelly-fish. Many of the Zoophytes.
ECHINODERMA	*Asteroidea*	Star-fishes.
	Echinoidea	Sea-urchins.
	Crinoidea	Sea-lilies.
	Holothuroidea	Trepangs.
PLATYELMIA		Flukes, Tape-worms, Planarians.
CHÆTOPODA		Segmented Worms and Gephyreans.
ARTHROPODA	*Crustacea*	Copepods. Barnacles. Shrimps. Crabs.
	Insecta	Halobates, &c.
MOLLUSCA	*Lamelli-branchiata*	Bivalves.
	Gastropoda	Whelks, &c., and Pteropods.
	Cephalopoda	Octopuses, Cuttle-fishes, &c.
TUNICATA		Sea-squirts, Salps, Pyrosoma.
VERTEBRATA	*Pisces*	Fish.
	Amphibia	Frogs.
	Reptilia	Turtles, Crocodiles, Snakes.
	Aves	Birds.
	Mammalia	Whales, Porpoises. Seals, and the terrestrial Mammals.

THE STORY OF LIFE IN THE SEAS.

CHAPTER I.

OCEANOGRAPHY.

ONE of the most important facts that has been established by modern investigations of the Sea is that there is no region in its vast extent that is entirely devoid of animal life. The surface waters in the Equatorial calms and the ice-cold waters between the ice-bergs of the Arctic regions are densely populated by animals, large and small; the heavy and heated waters of the Mediterranean and Red Seas, and the cold and comparatively fresh waters of the Norwegian fjords, the shallow waters of the coasts, and the greatest depths of the ocean beds all present us with their characteristic forms of living creatures. There is no Azoic region known to us. Wherever we use the trawl or dredge we may expect to find some representatives of the various classes of marine animals. But the seas exhibit so many varying conditions that, as we might have expected, the animals that characterise one region are absent from another; and while, in some places animal life is abundant, in others it is very scarce; just as on land we find the grass-lands and forests teeming with life, and the great

deserts and mountain tops inhabited only by a few solitary Lizards, Birds or Insects.

In order that we may fully understand, then, the nature of the problems concerning the distribution of animals through the seas, it is of importance to consider first the conditions under which they must live in the different parts of the ocean. A knowledge of geography is clearly necessary for those who study the distribution of terrestrial and aërial animals, and equally necessary is it for those who wish to learn something about the distribution of the aquatic animals, to consider first of all the rudimentary principles of hydrography. The principal Sea areas of our globe may be roughly divided into two groups: namely, the great oceans—the Atlantic, Pacific and Indian Oceans—and the Inland seas, which are partly enclosed by land, such as the German Ocean, the Mediterranean Sea, and the Red Sea. Taking the areas of the great oceans and the seas together, we find that no less than 141 millions of square miles, or nearly three-quarters of the surface of the globe, are covered with water. Moreover, these great areas are continuous, so that it would be possible for an animal, other conditions being favourable, to pass from any one sea, such as the Black Sea, to any other, such as the Hudson's Bay, without leaving the water,—an important fact in the consideration of the distribution of marine forms of life.

The depth of the sea varies very considerably in the different parts of the world. In the inland seas the water is comparatively shallow, but in the great oceans it is very deep. In the middle of the North Sea, for example, we should not expect to find a depth much exceeding 250

fathoms, but in the Atlantic or Pacific Ocean we have to pay out more than 2000 fathoms of the sounding line before the bottom is reached. In some parts of the ocean-basins a few very deep holes or furrows may be found in which the depth exceeds 4000 fathoms, or 24,000 feet. One of these deep holes occurs in the Atlantic Ocean, a little to the North of the Virgin Islands in the West Indies, and there is another in the Pacific Ocean close to the coast of Japan; but the greatest depth that has yet been found is one recently discovered by H.M.S. "Penguin" off the coast of New Zealand of over 5000 fathoms. Apart, however, from the fact that these very great depths are only of local occurrence, the areas of deep water—that is, of more than 2000 fathoms—are so much greater than the areas of shallow water, that when we make a calculation of the average depth of the sea we find it is no less than 2100 fathoms, or 12,600 feet.

The temperature of the sea is another feature which undoubtedly influences very greatly the character of its Fauna. The main source of the heat of the sea is the sun—for the heat derived from submarine volcanoes must be comparatively so small that we may omit it from consideration. Consequently we find that in the Equatorial regions the surface waters of the ocean are warmer than they are in the Temperate regions. These, again, are warmer than in the Arctic circles. But water is well known to be a bad conductor of heat, and therefore the direct influence of the sun affects only the most superficial layers. In the Equatorial region of the Pacific Ocean, for example, the surface temperature is sometimes as high as 80° F., at 100 fathoms from the sur-

face it is only 60°, at 400 fathoms only 45°, and at 1000 fathoms only a few degrees above freezing point. On the land the temperature falls as we pass from the coast to the high plateaux and mountains, and we find snow-capped mountains in Central Africa just as in Switzerland or Norway. In the sea the temperature falls as the thermometer is sent deeper from the surface. Just as on the land the snow line of the mountains is reached at high altitudes in the Tropics, at lower altitudes in the Temperate regions, and in the Arctic circle at the level of the sea, so in the sea the cold water that is found 500 fathoms below the surface in the Tropics, reaches a higher level in the Temperate regions, and is at the surface in the Arctic circle.

There is however one important point of difference between the distribution of these low temperatures on the land and in the oceans, in that they are broken in the former, and continuous in the latter. If we were to imagine an aquatic animal that could only live in temperatures below 35° F., it would be able to travel below the surface from one pole to the other, or from one ocean to another; but it would be impossible for a terrestrial animal, exhibiting the same peculiarity, to leave the Arctic circle or the Alpine region without traversing lands where the temperature is higher than that which is necessary for its existence. It might be supposed from what has just been said that the temperature of the water at the bottom is constant for the same number of fathoms of depth. This is not, however, the case. The temperature of the sea-bottom of the great ocean beds is approximately the same, varying from 28° F. in the Atlantic to 35°

F. in the Pacific; but in places where main basins occur, surrounded on all sides by shallower ridges, the temperature of the bottom of the basin is the same as that of the lowest ridge. For instance, the temperature of the bottom of the Sulu Sea, lying between Borneo and the Philippines, is 40° F. at a depth of over 2000 fathoms. Again, the temperature of the Red Sea is as high as 70° F., although depths of 1200 fathoms occur in its central portions; and this is the same as the temperature at the Straits of Babel Mandeb, which are 200 fathoms deep, and form the only outlet to the open ocean. These facts probably cause considerable modification in the character of the animals inhabiting such enclosed basins, but further investigations are needed before we can arrive at any very definite conclusions in the matter.

Another important element that must be taken into consideration in studying the environment of marine animals, is the quantity and character of the salts held in solution by the sea-water. In the first place we must remember that the sea-water normally contains a far greater percentage of salts in solution than the water of rivers and lakes, and this causes it to be very much heavier. If a tumbler be half filled with sea-water, upon which some fresh water is slowly and carefully poured, there will be for some time very little mixture of the two fluids, the heavier sea-water remaining at the bottom, and the lighter fresh water at the surface. Now the density of the sea-water, or in other words the amount of salts in solution, is not the same over the whole world, and the differences that may be observed in this respect are due, in most cases, to the simple

physical principle just enunciated. If we could imagine a river pouring its waters into a perfectly calm, tideless sea, we should be able to trace the fresh river water far away from the coast, for it would simply float on the heavier sea-water without mixing with it to any appreciable extent. In most cases, however, the tidal-waves, rushing up and down the river estuaries, stir up the fresh and salt water together, and cause a very considerable mixture, so that the water becomes either distinctly salt or brackish. Where very large quantities of fresh water are poured into the ocean, as, for example, at the mouth of the Amazon or the Mississippi, the surface water remains so fresh that the salt taste can hardly be appreciated at a distance of some miles from the coast. This fact sufficiently indicates the influence of great rivers upon the density or saltness of the sea-water in their neighbourhood, and the reader will be prepared for the statement that many inland seas, such as the Black Sea, are appreciably less salt than the great oceans.

Again, the ocean water itself is not of the same density in all latitudes. In regions where there is a copious rainfall and the sea is not frequently disturbed by severe storms, the rain takes some time to mix with the heavier salt water on which it falls, and consequently there may always be discovered in these localities a thin stratum of comparatively fresh water on the surface of the ocean. In some inland seas where there is considerable evaporation and a slight rainfall, as for example, the Red Sea and the Mediterranean, the sea-water reaches an even higher degree of concentration than it does in the open ocean. The following table will serve to illustrate these facts:—

Density of rain-water, 1.00.
Density of the Black Sea surface, below 1.025.
Density of the Atlantic Ocean surface (west of the Canaries), 1.0275.
Density of the Mediterranean Sea, over 1.028.
Density of the Red Sea, 1.030.
Density of the bottom water of the Atlantic, 1.029 (west of the Canaries).

That the rate of movement of the water influences very largely the character of the animals that live in it, is a fact that it is not necessary to discuss fully in this place; but as it is undoubtedly one of the factors which must be taken into consideration in discussing the character and possible origin of the Fauna of any particular region, a brief survey must be given of some of the principal causes of the movements of the water and the characters of the tides and currents which are manifest in the sea. Twice every twenty-four hours the water of the sea rises and falls. This movement is due to the attracting influences of the sun and moon, and is, as is well known, greater when the moon is full and when it is new than at the intermediate times. If the distribution of land and water on the surface of our globe were different, and a free waterway occurred round the world, right in the Equatorial band we should probably find a double tidal-wave rushing round the earth every twenty-four hours. As it is, however, the great tidal-wave is checked by the continents, and as it approaches the coasts is retarded and diminished in force. In Archipelagoes and along broken coast lines the tidal-waves produce true surface currents, which frequently run with great rapidity and exert considerable corroding action upon the rocks. In many estuaries and

bays the tide rushes in with such force that the water is heaped up to a great height against the land. At the entrance to the Bay of Fundy, for example, the rise at spring-tides is no less than 70 feet, and at the Cardiff docks the difference of level between high and low spring-tides is 42 feet. The tumultuous ebb and flow of such masses of water along the coast is fatal to some forms of animal life and favourable to others, and so to some extent it modifies the character of the Fauna.

In addition to the surface currents of the coast, produced by the tidal-waves, there are also the true ocean-currents, which must be briefly considered. They are caused by the winds which blow constantly in a definite direction across the oceans. The prevailing winds not only raise the sea into waves, but drive the superficial layers of the water over the subjacent layers in one direction. In studying a map of the great ocean-currents, we notice a well-marked one lying to the North of the Equator in both the Atlantic and Pacific. This flows from East to West and follows very closely the lines of the prevailing winds in that region. Similarly in the temperate regions of the Southern Hemisphere there is an ocean-current, flowing however in this case in the opposite direction—from West to East—and so corresponding with the trade-winds of that part of the world. The well-known Gulf-stream of the North Atlantic, although modified in some respects by other more complicated causes, also follows for part of its course the general direction of the prevailing winds.

The currents just described are surface currents only, and do not affect to any great extent the

mass of the subjacent waters in the ocean-basins. It is difficult to estimate the depth to which their influence reaches, but it is not probable that it extends more than 200 fathoms below the surface. In addition to these, there is also a series of slow currents in the deep waters flowing in definite directions. In the tropical regions the waters are constantly being heated by the sun, and passed away by the trade-winds to the North and South and ultimately towards the poles. In their long and complicated journey they are gradually cooled down until, in the regions of the ice-bergs, they reach a temperature just above the freezing point of sea-water. Here the water, being colder and therefore heavier than that of the other regions of the world, sinks to the bottom, and gradually returns in a deep-seated mass towards the Equator, where, welling up from the bottom, it replaces the heated layers of the surface. It is almost impossible to determine with accuracy the rapidity and exact direction of these deep-sea currents. It is extremely probable that they are immensely modified by the irregularities of the bottom and the outline of the coast banks, but their exact topography must remain for the present one of the secrets of the abyss that are not revealed to us. All that can be said is, that the warm surface water which passes from the tropics towards the North and South is replaced by deep-seated Polar currents, which account for the extremely cold water that is found at great depths in the ocean-basins, and also for some of the peculiarities of the marine Fauna, which will be referred to later on.

The character of the sea-bottom in various

parts of the world must be referred to before passing on, for there can be little doubt of the important effect it has upon the Fauna. In the neighbourhood of continents the bottom of the sea varies very considerably. The great rivers bring with them in suspension the products of the wear and tear of mountains and valleys; the coast line, washed by the continuous ebb and flow of the tides, contributes some of its substance to the formation of the sea-bottom; and the countless millions of animals and plants of the shallow waters leave their skeletons and shells as they die to form an integral part of the floor of the ocean. Thus the sea-bottom in the neighbourhood of the land is formed partly by terrigenous deposits, varying of course in character with the geological nature of the land itself, and partly by the animal and vegetable deposits of the coast. In some cases the deposits brought by the rivers can be traced in the sea-bottom for a very great distance from the coast. The characteristic mud of the Congo river can be traced 600 miles from its mouth, and it is said that the Arabian Sea and the Bay of Bengal are carpeted for 1000 miles by the mud brought down by the Ganges and the Indus. Leaving out of consideration, however, for the moment the exceptional cases of such large rivers as these, we may say that the influence of the land deposits upon the character of the sea-bottom extends to a distance seawards of about 250 miles. If we had a complete and careful survey of all the coast lines, it would be possible for us to draw a line round the great continents marking the limit of the deposits of river and coast mud. This line has been called the mud line by Mr. John Murray, and, as he has clearly

pointed out, it is characterised by an abundant and extremely interesting Fauna.

The sea-bottom, then, within the limits of the mud line, is very largely composed of deposits from the land brought down by the rivers. In some volcanic regions of the world this is, to a great extent, augmented by lava and water-logged pumice, and in other districts by the mud and stones dropped by the melting ice-bergs. The influence of animals and plants upon the formasion of the sea-bottom is often very great indeed in shallow water, though it varies considerably in different parts of the world. In the neighbourhood of the British coast, for example, the sea-bottom is, in many places, carpeted with the calcareous Sea-weed, *Lithothamnion*,—in other places the dredge will come up crammed full of bivalve shells. But such instances as these in which the floor of the sea is covered with animal or vegetable shells, are comparatively rare and of small extent in the neighbourhood of land in the Temperate regions, and in nearly all localities the true terrigenous deposits can be readily obtained by the use of a small-meshed dredge. In the warmer regions of the world, however, the sea-bottom in the shallow water is over great areas completely covered by animal and vegetable products. In the West Indies, and in some parts of the Eastern coasts of Tropical America, in the Eastern Archipelago and the coast of East Africa and its islands, Coral reefs are found. These are entirely built up of the skeletons and shells of animals, and a few Coralline Algæ. In the vicinity of these reefs the floor of the sea is for miles carpeted with the broken-down skeletons of these animals, sometimes in the form of a fine coralline

sand, sometimes of large lumps studded with knolls of living Corals, Molluscs, Sea-urchins, and other creatures. We find, therefore, in the warmer regions of the world immense areas of shallow water in which the terrigenous deposits take but a very small part in the formation of the sea-bottom, animal and vegetable life being so vigorous and active as to be able to form enough shells and skeletons to cover every available part of its surface.

Far away from continental lands, and at great depths, the character of the sea-bottom completely changes. At a distance of 100 miles from the coasts of America or Europe, for example, the land deposits have already found their resting place, and the animal life in the depths of the Atlantic is poor in skeleton-forming genera. However, the surface waters of the ocean teem with creatures of all sorts which, as they die, drop down their skeletons and shells in a gentle shower to form a fine deposit on the bottom. When we get beyond the mud-line, then, and use the dredging or sounding apparatus in depths of 1500 to 2500 fathoms, we find that the bottom is largely composed of the shells of such surface animals as the Pteropods and Globigerinas, and according to the relative abundance of these forms it is called Pteropod Ooze or Globigerina Ooze. In still greater depths than these the character of the bottom again changes, and we find a deposit which is commonly known as the Red clay. The explanation of this change of character depends

FIG. 1.
Globigerina shell from a deep-sea ooze.

upon the fact that sea-water exercises a slightly solvent action upon carbonate of lime, and the shells of the Globigerinas and other forms are, in seas of a depth of over 2500 fathoms, dissolved before they can reach the bottom. The only shells that can survive this long journey are the siliceous shells of the Diatoms and Radiolarians, and in those parts of the ocean where these organisms live in abundance their empty shells form

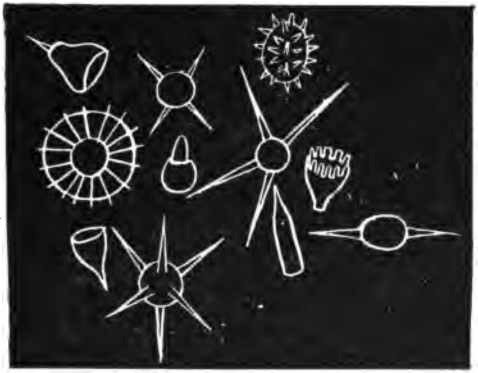


FIG. 2.—Radiolarian shells from a deep-sea deposit.

an important percentage of the composition of the Red clay. Over a very considerable area of the Pacific Ocean, however, the Red clay contains only a minute proportion of these shells, and its composition has given rise to a good deal of discussion among the authorities. It may be considered to be a conglomerate of the horny fragments of dead surface-living animals, of volcanic and meteoric dust, and of small pieces of water-logged pumice-stone.

In some of the very deep holes of the Pacific Ocean the mud is almost entirely composed of Radiolarian shells, and is then called "Radiolarian ooze": and in the Southern Sea a mud called Diatom ooze has been found, which consists principally of the siliceous shells of these minute algæ. Notwithstanding these varieties of the mud, and others that space does not allow me to refer to at length, we may suppose that if the floor of any one of the great oceans were exposed it would have the appearance to a traveller of a vast desert-like expanse, without a stone, a rock, or a cliff to vary the monotony of the scene. At one time it was supposed to be an absolute plain, without any important change of level from the mud line of one continental coast to the other; but the result of modern submarine explorations has been to prove that in all the great ocean-basins, hills and ridges, as well as troughs and deep holes occur, which break the monotony of the generally smooth and level character of the bottom.

CHAPTER II.

SHALLOW-WATER FAUNA.

HAVING considered thus briefly the general conditions under which the animals of the sea must live, we may now consider more in detail the special conditions of shallow-water life.

In water of only a few fathoms in depth, the direct light of the sun is capable of reaching and influencing all living things that occur, either at the bottom, at the surface, or in the intermediate

waters. Great as the influence of direct sun-light must be upon animals, it is even greater upon plants. Nearly all the Sea-weeds are, like the plants of the dry land, dependent upon carbonic acid gas dissolved in the water for one of the most important constituents of their food, but it can only be absorbed by the plant in the presence of sun-light. It is possible, therefore, for Sea-weeds to flourish in the shallow waters of the sea, while they are necessarily absent from the deeper and darker regions to which the rays of the sun cannot penetrate. Everyone knows that in the shallow waters of every coast there is in many places a dense tangle of Wracks and long, flat ribbon-like Sea-weeds growing on the bottom, and that on and amongst these weeds a rich harvest of animals awaits the eager shore collector. It is true that there are vast fields of sand on which the Sea-weeds are few and far between, but we may say that wherever they can obtain a secure foothold in the shallow waters of the British coast there they will grow and multiply in great profusion. We must not, however, jump too hastily to the conclusion that the same is true for all parts of the world. The British coasts are particularly rich in Sea-weeds, in fact a distinguished botanist once said that they probably present us with the greatest number of genera and species of any coast-line of the same extent in the world. In the Temperate regions of both the Southern and Northern Hemispheres there is generally a rich Sea-weed flora, but in the warmer regions it is less luxuriant, and on the Coral reefs of the Tropical seas it is remarkably poor.

Turning our attention for the present to the Temperate regions, let us consider the influence

that the Sea-weeds have upon the animals of the shallow waters. In the first place we find that they afford shelter and support for a large number of animals which could hardly live without them. In the roots of the weeds may be found little Crabs and Molluscs, which occur nowhere else; and clinging to the long waving branches are many forms of Sea-anemones, Zoophytes, flattened limpet-like Molluscs, Ascidians, and other forms of animal life. The great forests of weeds are also the haunts of many queer Fish, Prawns, Crabs, and Sea-slugs, which hunt their prey or hide from their enemies amidst the shelter of the stems and branches.

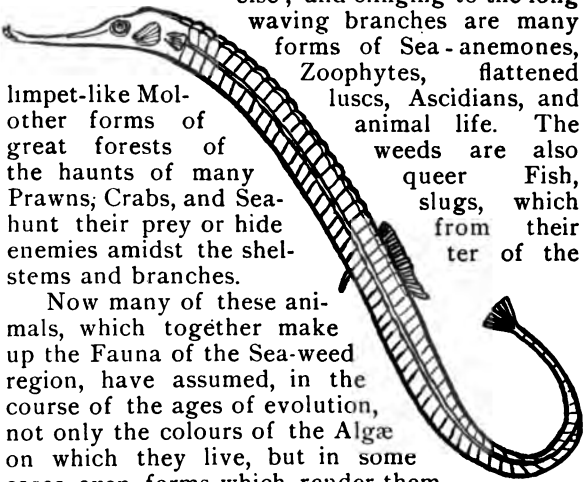


FIG. 3.
The common Pipe-fish.

Now many of these animals, which together make up the Fauna of the Sea-weed region, have assumed, in the course of the ages of evolution, not only the colours of the Algæ on which they live, but in some cases even forms which render them at first sight more like plants than animals. The slender Pipe-fish, for example, which is not uncommonly found amongst the bright green Sea-weeds of the coast, is wonderfully similar, both in form and colour, to the weeds on which it lives. The Sea-horses, which have such a curious form out of the water, in their natural surrounding resemble the weeds so closely that they may be easily overlooked. A still more remarkable example is to

be found in the curious fish Phyllopteryx, in which the body is provided with long branched processes, making it we may suppose much more difficult to distinguish in its natural haunts than even the Pipe-fish or Sea-horse.

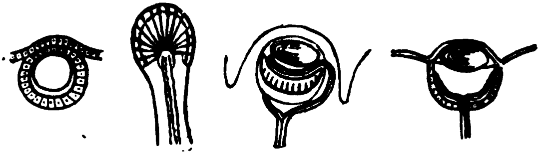
Many other examples to illustrate this feature of the Sea-weed Fauna could be quoted, but suf-

FIG. 4.—Phyllopteryx.

ficient has been said at present if we have indicated to the reader the manner in which, by the indirect influence of light, the form and colour of animals may be modified for their life among the marine plants. The presence of light, however, modifies directly the character of the animals themselves in many respects.

The statement that many of the animals of the shallow water are provided with eyes because

there is light is, when carefully examined, found to be strictly true, however anomalous it may seem to be. There must have been light in the shallow waters of the sea when the first primordial forms of life made their appearance, and it was



A B C D

FIG. 5.—Diagrams of eyes of Whelk, *A*; Lobster, *B*; Scallop, *C*; Fish, *D*.

this light which, step by step, led to the evolution of the most complicated and perfect forms of eye from the simplest pigment spot of the Protozoan to the eye of the Lobster and the Fish. We may say that all animals that freely swim in the shallow waters or that crawl and creep on the rocks and sands at the bottom are provided with eyes. The Fish are provided with a pair of eyes which present us with the same general features that we find in the other Vertebrates. Lobsters, Crabs and Prawns have each a pair of stalked eyes, which are probably as perfect in their functions as the Vertebrate eye, although built up on an entirely different model. Whelks, Winkles, and other Gastropods, although so slow in their movements, have each, upon or close to their tentacles, a pair of minute eyes, which are much simpler and probably far less perfect in form than the eyes of their more highly organized neighbours. Even the little Jelly-fish, Star-fish, Sea-urchins, and other creeping forms of life, are provided

with specialised pigment spots, which we have good reason to believe enable them to perceive the rays of light.

But we must notice that it is only the animals that are capable of locomotion from place to place that need these organs of vision, and that the stationary forms are blind. In the large class of the Lamellibranchs, for example, to which the Oyster and the Mussel belong, we find that with a few exceptions there are no eyes. These animals, after the first few stages of their life are past, settle down into the sand, or fasten on to a rock and remain there until their life is done. Their food, consisting of the minutest specks of animal and vegetable life, is brought to them by the sea-currents; they do not need nor desire to seek the society of their relations, and when their enemies approach they resign themselves almost without an effort to the inevitable. To such animals eyes would be useless, and so nature has withheld them.

There are, however, a few Lamellibranchs that possess good eyes, eyes that are almost as complicated in their structure as the Vertebrate eye; and not a single pair only, but sixty, eighty, a hundred, or even more, may be found on a single individual. Such a Lamellibranch is the common Scallop which may be seen in many of our fishmongers' shops. Unlike most of the group, this animal is able to make long flights through the water by the flapping together of its shells, and there can be no doubt that on the approach of danger it uses this method of locomotion for escape. One of its most deadly enemies is the Star-fish, which forces the shells apart and sucks out the flesh by means of its

protrusible stomach. When a Star-fish is placed in an aquarium in which there are some Scallops, lying, as they do, on their sides, with the valves slightly open, showing the double row of gleaming metallic eyes on the margin of the mantle, the Star-fish immediately moves, with what in such an animal may be considered extraordinary rapidity, straight in the direction of the Scallop. Before, however, it reaches its prey, the coveted victim gives four or five vigorous flaps of its shells and swims away to another part of the tank. This suggests that the eyes of the Scallop are used in the light as a means of giving warning of the approach of an enemy, and they are found in the Scallops only, among common British bivalves, because they alone possess this power of swimming away. Of course if there were no light in the water the eyes would be useless, and it is an interesting fact that the Scallops which live in the darkness of the great depths of the ocean are quite blind.

Very interesting examples of the connection between the presence of eyes and the power of locomotion are found among the sedentary or fixed forms of life. The great class of Sea-squirts or Tunicates include a number of genera, most of which are, in the adult condition, immovably fixed to the bottom, and in that stage have no eyes; but the eggs which they produce give rise to little creatures, like tad-poles in form, which swim about freely in the water. Each of these tad-poles has a large eye in its brain, which remains so long as the animal leads a free life. As soon, however, as it settles down upon the rock which is to become its permanent resting place through life, the eye and the organ of locomotion,

the tail, both degenerate and ultimately disappear. Again, we often find upon rocks, Sea-weed, old shells, and the like, some curious delicate branching organisms called Zoophytes. Notwithstanding their general resemblance in form to Sea-weeds, these Zoophytes are known to be animals. Each tuft or branch is formed by a number of delicate little Polyps, each with a crown of tentacles round a terminal mouth. The Polyp cannot move away from the branch it grows upon, nor the branch from the stem, nor the stem from the rock on which it rests, and none of these minute creatures are provided with eyes. There are, however, a few Zoophytes that give rise to buds, which grow into the form of minute Jelly-fish (or Medusæ, as they are called); and these, becoming detached from the parents, swim away and lead an independent existence. These Medusæ are in many cases provided with simple little eyes. During their short life they are drifted away by the sea-currents to some distance from their parents, and produce a number of eggs which are capable of developing into a new fixed colony of Polyps.

FIG. 6.—A branch of the Zoophyte Obelia.

FIG. 7.—Medusa produced by Obelia.

We may consider it one of the maxims of Science that in a population of animals which possess eyes, colour as well as form is of extreme importance. As well as the alteration in form that takes place in the animals living among Sea-weeds, we find a modification in colour in the creatures dwelling among rocks or on the sand, so that they may resemble the ground on which they live. No more striking example of this could be found than in the common Shrimps of all coasts. Anyone who has watched them in the sea-pools must have been struck with their close resemblance to the sand. In fact it is only by close observation that they can be distinguished from it. In an aquarium,.too, it may be observed how very much the upper sides of Soles, Flounders, Turbots and other flat fishes are like the sand in colour, while the under sides are almost invariably pure white. The black colour of the Lobsters, speckled and striped with blue, has a close resemblance to the holes and crannies of the rocks among which they live. The bright transparent green Prawns are almost invisible as they move about among the Sea-weeds, and Sea-slugs assume all manner of beautiful colours according to the ground on which they feed.

On the Coral reefs of the warmer regions of the world the pools that are left when the tide goes down are characterised by their brilliancy of colour. The bright purple, green, and yellow tips of the Coral branches, the red and bright green Sponges, and the white pieces of dead and broken Corals make up a scene of beauty which can only be compared with a bed of variegated flowers. Here the Fish, Prawns, and other moving animals have assumed the most gorgeous

colours in patterns of spots and stripes which verily astonish the naturalist when he sees them for the first time. The great Sea-perches, with their sides covered with bright red or brown blotches, the curious Trigger-fish, with bright red, blue, or yellow bands crossing their bodies, the banded Lobsters, and the spotted Cuttle-fishes, strange and conspicuous as they may seem when they are taken out of the water, are in life but in harmony with their surroundings, and, in reality, less conspicuous than they would be if less brilliantly arrayed.

I remember on one occasion as I was watching some expanded Polyps in a little shore pool in the Tropics, I noticed something suddenly move close to the coral block on which I was standing. As there was no escape from the little pool, nor any holes in which the creature could hide itself from my observation, I searched with diligence to find it again, but for a long time without avail. Suddenly it moved again, and then I saw, resting on the brilliantly coloured corals, a remarkable little Shrimp called by zoologists *Stenopus*. Its body, which was almost transparent, was marked by a number of bands of a bright red colour, it had enormously long antennæ similarly banded, and its legs and body were covered with short red-tipped spines. When I succeeded in safely landing it in my collecting bottle I felt perfectly astonished that I had been so baffled by such a lovely little jewel, so bright, so strange, and so generally conspicuous did it then seem to be.

The colours of the animals I have referred to hitherto may be accounted for by their need to escape the attention of their enemies, or to avoid

detection in the pursuit of their prey; but the animal colour problem is not yet exhausted. The beautiful colours of the Anemones, Corals, Sponges and many other sedentary forms of animal life, and the marvellous patterns on the shells of Molluscs cannot be due to these causes. Many ingenious theories have been brought forward to explain away the difficulty, but none of them seem to be perfectly satisfactory, and consequently it is unnecessary to enunciate them in detail in this small book.

The character of the bottom of shallow water, especially in the neighbourhood of the coasts, presents us with so many variations that it would be a long task to consider in detail all the different adaptations that the animals exhibit. The Fauna of the sand, shingle, and mud at the mouths of rivers, of the rocks of iron-bound coasts, and of the coral-reefs, each present us with many curious kinds of modification of form and structure. A brief reference to one or two characteristic regions must be made before passing on.

The sandy bottoms which are so prevalent, not only upon our coasts, but in nearly all parts of the world, invariably support a Fauna with many curiously altered forms. In walking across the sands at low water we may have often noticed many worm-like and twisted columns of sand; these are the casts of the common Lug-worm, which is a favourite bait for many kinds of Fish. The Lug-worm lives in a U-shaped tube, which it forms from a slimy secretion of the body; it feeds by swallowing the sand in which it burrows, extracting from it as it passes through the intestine whatever animal or vegetable food

it may contain. There can be little doubt that the sand is a very poor form of diet, and that an immense quantity must pass through the body of the animal compared with its weight in order to afford sufficient nourishment. It has been reckoned that as many as 82,433 casts may be found on an acre of sand where conditions are favourable for these Worms, and that they would weigh together nearly 2000 tons. This would mean that the whole mass of the sand would pass through the bodies of Lug-worms on an average of once in every twenty-two months.

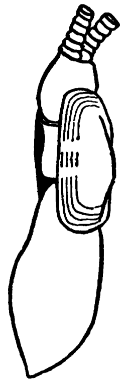


FIG. 8.—A Bivalve Mollusc, showing below the foot with which it burrows into the sand, and above the siphon.

But the Lug-worm is only one of the many forms of life that burrow in the sand. A very large number of bivalve Molluscs live with the greater part of their bodies perpetually buried. Their organisation is such that their food and the water that is used for respiration can be brought to them by a tubular prolongation of the body called the siphon. Some of these animals live much deeper down than others, and while some have but feeble powers of moving either up or down in their burrows, others can penetrate to great depths with extraordinary rapidity.

The shell of a Lamellibranch, called the Razor-shell (*Solen*), is not an uncommon object of the sea-shore where stretches of sand occur. When the animal is alive it has the power of burrowing down so quickly that it is practically impossible for one man to capture a specimen by digging,

when it is thoroughly alarmed. Occasionally, however, the sea itself, when lashed into fury by a storm, is a better digger than the Solen is a burrower; and after a heavy storm in the Isle of Man I have seen the shore littered with Solens scooped out of the sand by the force of the waves and cast up with lacerated shells to fall an easy prey to the Seagulls.

The sandy bottoms in shallow waters are also the haunts of many kinds of Fish that are specially modified in form and colour to resemble their surroundings. The large family of the Skates have their bodies compressed from above downwards so that they can lie perfectly flat upon the sand. Their upper surface is deeply pigmented, giving them a general resemblance to the ground on which they lie; but to assist them in escaping observation they have a habit of shaking their fins in such a manner as to scatter a considerable quantity of sand over their bodies. Thus it can well be understood that in the dim light of the sea-bottom the little Fish and Shrimps, which form a large portion of their food, may approach quite close to them without being in the least aware of the danger into which they are running. The upper side of the Skate is also armed with a number of sharp and hard spines, and in some forms—called the Sting-rays—one of these, situated at the base of the tail, is much larger than the others, and provided with muscles so that it can be suddenly erected. In connection with this spine there is a poison-gland and duct. The wound that is inflicted upon the arms or feet of the fishermen by this formidable weapon of offence is said to be of a very serious nature.

Some of the Skates, too, show another very interesting modification of structure, which, however, is not directly associated with their mode of life, but may be briefly referred to here whilst dealing with the family. This is the electric organ. In the younger stages of the common English Skate a small region of the muscular system on each side of the base of the tail becomes changed into an electric organ, but the discharges which it is able to give are so feeble that they can only be appreciated by a galvanometer. In the Torpedo, however, the electric organs are very large indeed, and situated one on each side of the head. They can give a shock which is powerful enough to kill small animals and to stun larger ones. With such a formidable weapon of offence and defence, it is clear that the need for active movements is considerably diminished, and the Torpedoes are described as being exceedingly slow in progression and incapable of the violent movements of other Skates.

The other Flat Fishes found on sandy bottoms belong to a different group altogether, and are characterised by their bony skeletons and other features. The Soles and their allies do not, like the Skates, lie flat upon their bellies, but are *laterally* compressed and lie upon one side. The side which is habitually uppermost is of the colour of the sand, and the other almost invariably

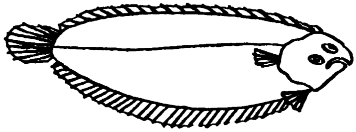


FIG. 9.—The common Sole, showing both eyes on one side of the head.

pure white. In the course of their development the Soles undergo very extraordinary changes in form to reach the perfectly flattened condition of the adult stage. These changes affect many of the organs of the body, but perhaps the most in-

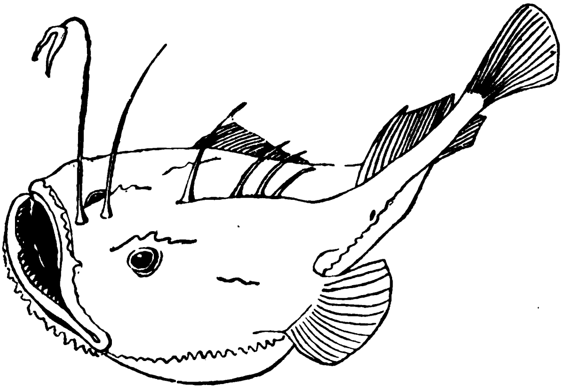


FIG. 10.—The Angler.

teresting of all is the history of the eyes. In the young Soles, which swim almost vertically, like the majority of fishes, there is one eye on each side of the head, but as they grow older and gradually take to the habit of swimming on one side, the eye of that side sinks down into the head, and rotating as it goes passes through to the other side. This process naturally leads to a considerable distortion of the skull, so that the bones of the adult Sole show as complete a want of symmetry as can be found in any Vertebrate.

Some of the Bony Fish, however, that live on the sand are flattened dorso-ventrally like the Skates. The Angler or Fishing-frog, for example, is a Flat Fish, which is perfectly symmetrical. Like the other Flat Fish its upper surface is coloured in such a manner as to resemble the ground on which it lives. Its great mouth, armed with formidable rows of sharp-pointed teeth, is directed upwards, and it receives its name from a curious tentacle terminating in a brightly-coloured knob which dangles over its mouth. The brightly-coloured knob looks no doubt a tempting morsel to the little Fish upon which the Angler preys, but the greed or curiosity, whichever it may be, that induces them to inspect the bait leads them to the fate which follows one snap of the great tooth-armed jaws.

The Fauna of the shallow waters where rocks abound also possesses many peculiarities. In the first place we must remember that the rocks, being firm and hard, present a basis upon which many of the sedentary forms of life that would be swept away or smothered if they attempted to live on the ever-shifting sands, can fix themselves. Consequently the rocky bottom is characterised by a rich Fauna of those groups of animals, which, in the adult condition, are immovably fixed. If a large stone or a water-logged piece of timber that has been at a depth of a few fathoms for some months or years be captured in the dredge and brought on board for examination, it is sure to present the observer with a multitude of firmly-fixed creatures. Among them there is almost certain to be found a number of small conical shells, made up of a series of triangular plates, fixed to the rock by their

bases. These are commonly spoken of as Barnacles (*Balanus*), and they pass through an interesting history. For many years they were considered, from the character of their shells, to be allied to the Molluscs, but an examination of the soft parts of the animal shows that, unlike any Molluscs, they are provided with six pairs of jointed legs; and a still further study of their anatomy proves beyond a doubt that they can no longer be classified, with any pretence of scientific accuracy, with that group.

FIG. 11.—Vertical section of a Balanus, showing animal in situ in its shell.

The secret of their true relationship was not discovered until the story of the development was worked out, when it was found that the eggs they discharged each gave rise to a little larva called Nauplius, which is provided with three pairs of legs like the larvæ of some of the Prawns and their allies. The result of these observations then was to prove that the Barnacles are really Crustaceans, notwithstanding the fact that, unlike most of that group, they are, in the adult stage, permanently fixed to the rocks.

On the same piece of stone there will most probably be found several twisted or coiled tubes of lime, formed by a little Sea-worm called Serpula. When living in the water the head of this worm projects from its shell and expands a circlet of delicate tentacles, by means of which the food is brought to the mouth. One of these tentacles

is specially modified and enlarged at the extremity to form a conical knob, which, when the animal is retracted into the shell, closes the aperture like a stopper.

Then there may be found some spherical or lobate masses of a fleshy consistency, white, pale pink or yellow in colour, and studded with numerous star-shaped apertures. When these are allowed

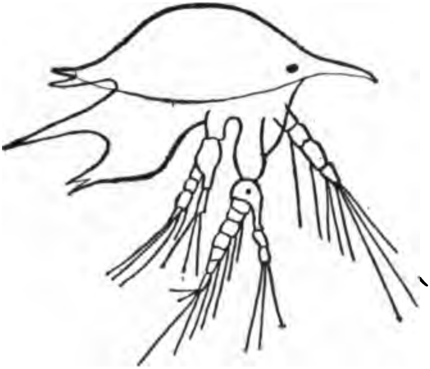


FIG. 12.—Nauplius larva of a Balanus, enormously magnified.

to remain in a basin of fresh sea-water for some time, each one of the star-like apertures opens, and a beautiful transparent little Polyp with eight feathered tentacles gradually unfolds itself, only to be slowly withdrawn into the mass when the vessel is shaken or otherwise disturbed. These Polyps form colonies, known as *Alcyonium digitatum*.

Now it is to be noticed that none of these three examples of the sedentary Fauna can move in the least degree from the rock or shell to which they

are fixed. When once the young larva has taken up its position there it must remain until old age or some disaster brings its life to an end. When they are first hatched from the egg that is thrust into the water by the parent, they pass through a larval stage that, like the Nauplius of the Barnacle, is active and free. Then they are carried away from the parent stock partly by their own active movements, but more particularly by the tides and currents of the sea-water. At last a change in their structure occurs. They sink to the bottom, become attached to a rock or stone, complete their metamorphosis, and remain anchored to the spot for the rest of their lives.

The number of different forms of animal life which constitutes this sedentary Fauna of rocky coasts is very great indeed. In addition to the Barnacles, Worms and Alcyoniums, there are numerous species of Sea-anemones, Sponges, Corals, Zoophytes, Sea-squirts, and other forms, and in *all* these cases the eggs give rise to free swimming larvæ, by which the distribution of the species is effected.

Another group of animals, which forms an important feature of some rocky coasts, are the Boring-molluscs. The Rock-borers belong to many different species. Some of them, such as the Pholases, make long cylindrical holes in chalk, and even in harder rocks. The Teredo is the borer, commonly known as the Ship-worm, on account of its powers of penetrating into timber. The long calcareous tube which it forms as it works its way into the wood, gives it a superficial resemblance to a large sedentary worm, but it is in reality a bivalve Mollusc, specially modified in structure for its peculiar habits.

The next group of animals we have to consider in the Fauna of the rocks includes all those that slowly creep or crawl, without possessing any powers of rapid locomotion. Amongst these may be mentioned the Sea-urchins and Star-fishes. The former possess spherical or heart-shaped bodies covered with a formidable array of spines, among

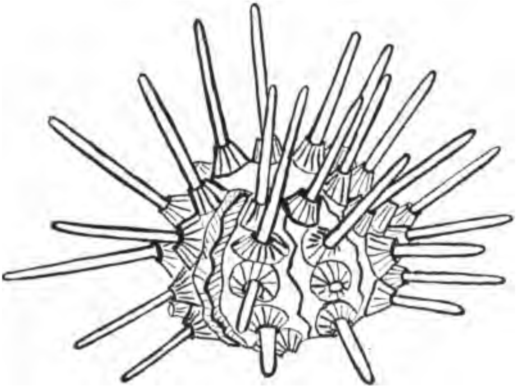


FIG. 13.—Sea-urchin with large thick spines.

which there protrude several rows of soft transparent tubes terminating in little cup-like discs. Some of these tubes—or tube-feet as they are called—are fixed to a rock, and the heavy body is slowly dragged after them; another set is then attached, whilst the former is released to obtain another hold a little further on. The progress is slow, but the Urchin is able to climb the smooth face of an absolutely perpendicular rock with perfect ease or to get over any other obstacle that may be in its path. The Star-fishes are similarly

provided with tube-feet, but in their case these are confined to the lower surface of the body, the upper side being entirely devoid of them. Star-fishes have a very wide distribution in the sea, and occur on sandy shores as well as among rocks and shingles. If a specimen be watched gliding slowly and smoothly over the sea-bottom and then the mouth be examined with a pocket lens, a doubt might arise in the mind of the young naturalist as to the justice of the charge that is made against these animals of their being the principal enemies of the hard-shelled Oysters. But the charge is well founded, for if a Star-fish be placed in an aquarium with an Oyster or a Cockle, or, in fact, almost any bivalve Mollusc, it may be seen to clasp its prey in its arms and slowly but firmly and surely force open the shells, and then protrude on to the soft parts a long tubular stomach which gradually digests and absorbs them. The Star-fishes, then, are undoubtedly to be reckoned among the most voracious and destructive inhabitants of the shallow waters, and it is probable that the covering of spines which we find so commonly among shallow-water animals is an adaptation to prevent or render difficult the operations of these creatures.

The Gastropod Molluscs form another large and important group of creeping animals of rocky coasts. On nearly all British coasts numerous Periwinkles may be seen clinging to the rocks at low tides, and if a search be made in the deeper pools and on the rocks nearest to the low-water marks many other species will be found of animals with spirally-coiled shells which are included in this group of Gastropods. The Periwinkles on the rocks might at first sight be thought to

belong to the sedentary group of animals, but when the water covers them again, or when they are put into an aquarium, they may be seen to protrude a head and an elongated slimy foot, which, gliding over the surface of the rock, drags the great shell and its contents with it. On the approach of danger the foot and head are withdrawn into the shell, and the animal rests secure from many enemies that might otherwise have found it a dainty morsel. Some of the Gastropods are purely vegetable-feeders, but most of those living in shallow sea-water feed upon Molluscs and other animals. It might well be a matter for wonderment when the soft head and little mouth of a Gastropod, such as a Whelk, are examined, that it is carnivorous and attacks and devours animals as large as itself. But the anatomist shows us that hidden in the recesses of that mouth there is a ribbon beset with numerous sharp little teeth, which by a complicated mechanism can be worked backwards and forwards in such a manner that it can bore a hole through very thick and dense shells; and, the soft parts being reached, a tube is protruded which dissolves and sucks them up into the animal's stomach.

Many people must have noticed that numbers of the bivalve shells that are cast up on the sand at low tide are perforated close to the hinge by a neat little round hole. This is the hole made by some predaceous Gastropod which, having killed its prey and devoured all that is digestible of it, leaves its empty shells at the mercy of the waves. Amongst the rocks numerous species of Gastropods are found, some undoubtedly carnivorous, others herbivorous. The many beautiful forms and colours that their shells assume may be seen

in any good museum or conchological cabinet. Some of them are very minute, others are provided with a shell more than a foot in length; some are marked with numerous coloured spots, others with bands or lines; some have perfectly

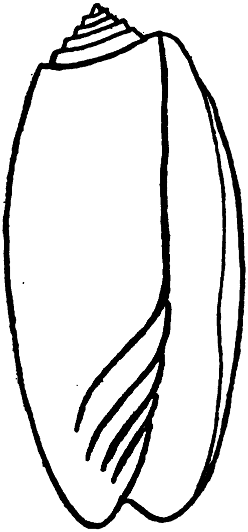


FIG. 14.
Smooth-shelled Gastropod.

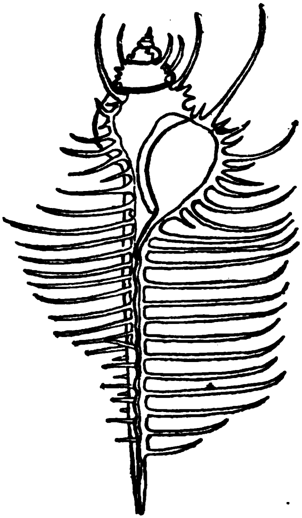


FIG. 15.
Spiny Gastropod.

smooth shells, others are ribbed or spiny. It is extremely difficult to account for all these modifications, partly because it is impossible to study the animals alive in their natural habitats a few fathoms below the surface of the sea, and partly because life in the shallow waters must be so complicated that we are at a loss to understand the

value to a species of slight modifications in structure such as these. The difficulty that has been found in explaining these various forms and colours has led some naturalists to the belief that they are of no importance to the species in the struggle for existence, that they are, as it were, the accidental result of some process of excretion, and not the outcome of a long series of slight changes, bringing about at length an adaptation of form most suitable to the habits of the animal. Such views are, however, to be accepted with great caution, and most zoologists will be contented to wait until our knowledge is much greater than it is at present, before wholly agreeing with them.

Another great class of animals which has many representative forms among the rocks is the group of Crustaceans. The Lobster, the Prawn and the Crab are all familiar examples of this class. They may be found by searching rock pools at low water, or can be captured in basket-work traps in places beyond low-water mark. When undisturbed they crawl slowly over the rocks and weeds by their long jointed legs, searching for their prey, but when alarmed the Lobster and the Prawn can, by violent flapping movements of their tails, dart rapidly backwards through the water, while the Crab beats a hasty retreat sideways into some shelter among the rocks. Like many of the Molluscs, the Crustaceans have a hard covering or shell to protect them from many of the dangers to which soft-bodied animals would be exposed, but a momentary glance at them would be sufficient to satisfy the most inexperienced eye that there are many and important differences in the character of the

shells of these two great groups of animals. One important distinction between them, however, might well escape observation, and that is, that whilst in the Mollusc the shell increases gradually in size during the life of the animal, in the Crustaceans it cannot do so. In the Lobsters and Crabs the shell is periodically cast off entirely, and for a day or two at each period the skin of the animal is quite unprotected. A new shell is gradually formed, and this is hardened and thickened until it assumes a form similar to that of the one that has been lost, but larger. During the moult the Crustacean usually hides itself in a hole in the rocks and waits patiently until the new shell has grown.

The animals included under the popular names of Cuttlefishes, Squids and Octopuses are also capable of crawling about among the rocks by their long feeler-like arms; but they are in the habit, as well, of making prolonged journeys through the water, by pumping the sea-water through a tubular siphon situated on the under side of their bodies. These animals possess in such a remarkable degree the power of changing colour that they might be called the Chamæleons of the sea. As they pass slowly through the water from one part of the coast to another the colour of the skin changes so as to resemble the colour of the rocks or weeds which are below them. These changes are brought about by numerous little bladders in the skin which are filled with different coloured fluids, and are worked by a complicated system of muscles under the control of special nerves from the brain. When the colour blue is predominant, it is found that all the bladders containing blue fluids are dilated, the

others being constricted; when the colour is red the red bladders only are dilated, and so on; and as the nervous response to the colour of the rocks perceived by the eye is practically instantaneous, the change in the general colour of the body brought about by the dilatations of these vesicles is extremely rapid. Many other animals have the power of changing colour, but in no group is the alteration more rapid and remarkable than in this order of Cuttlefishes and Squids. Another very interesting feature presented by these animals is their ability to discharge suddenly a cloud of inky substance into the water. Their principal enemies are the Whales, Porpoises and some of the larger Sharks and other Fish. When these animals approach, or any other danger is feared, the Cuttlefishes discharge into the water from a special bag, called the ink-sac, a quantity of black or brown pigment which, diffusing rapidly, forms a cloud round their bodies, in the obscurity of which they frequently escape pursuit. The well-known Sepia of painters is obtained from these ink-sacs.

FIG. 16.
A Cuttle-fish.

The last group of animals occurring among the rocks are those capable of vigorous swimming movements. Many Crustaceans, such as the Lobsters and Prawns, are capable, as has just been pointed out, of swimming rapidly through the water by means of their powerful tails. But this swimming power is only accessory to that of crawling or creeping, and is used merely when

the animals are disturbed. Cuttlefishes and their allies seem to spend a considerable portion of their time in floating or swimming in the water, but still they do crawl about among the rocks, and very probably attack and feed upon their prey entirely upon the sea-bottom.

The members of the Rock-fauna which belong to the class of Fishes very rarely rest upon the sea-bottom at all. They are not, as a rule, pro-

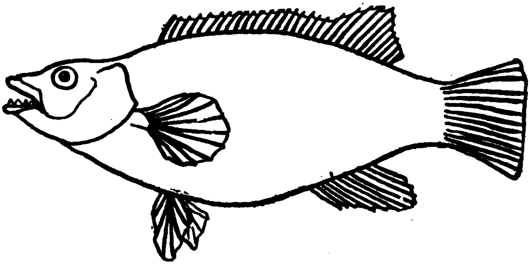


FIG. 17.—The Wrasse.

vided with limbs which are capable of crawling or creeping; and their mouths are adapted for catching food that is swimming, or of browsing upon or nibbling at fixed forms of life while their bodies are still floating in the water. Nearly all the animals living among the rocks that we have hitherto spoken of, have some organs or some specialised portion of the body-wall for resting upon or for attaching themselves to the bottom. The Anemones are attached by their bases; the Sea-urchins and Star-fishes crawl by means of their tube-feet; the Gastropod creeps over the rocks by its broad flat foot, and the Octopus stretches out its muscular arms and drags its body along

by the numerous suckers they bear. In the Flat Fishes of the sandy and gravelly shores we usually find a white under surface on which they rest when waiting for their prey. Among the Fish which frequent the rocks, however, such as the Cods, the Whitings, and the Wrasse, there are no such surfaces. The body of the Fish is usually more rounded in form, and no well-marked limit can be assigned to the coloured upper surface and the pale silvery under side. These Fish are in nearly all cases rapid and powerful swimmers, rushing through the water after their prey, or away from their enemies, by vigorous lateral movements of their tails.

A curious exception to this general rule among the Fish occurs in the family of the Lump-suckers. These Fish are found on the English, but more commonly on the Scottish coast, and are distinguished by the presence of a sucker, formed by the throat fins, on the under side of the head. By means of this the Lump-sucker is able to attach itself so firmly to rocks and stones that it can only with considerable difficulty be removed from the object to which it is attached.

Of the Fish that are commonly found among the rocks, a very considerable number migrate from time to time to other parts of the sea, and may be caught in the trawl on sandy or shingly bottom, or even in the drift nets at the surface of the sea. A large number of Fish belonging to the family of the Codfishes frequent the rocks during a part of their lives. The Pollack is distinguished from most of the others by the absence of a barbel on the lower jaw, and is one of the persistent rock frequenters. In the adult condition it feeds almost entirely upon other Fish, al-

though in the younger stages of its life Crustaceans, Worms, and other Invertebrates seem to form the bulk of its food.

The true Cod and the Haddock seem to have a much wider range, occurring on shingly bottoms, where they are frequently caught in the fishermen's trawls, as well as in the neighbourhood of rocks. The Hake feeds principally upon Pilchard, Herrings and Sprats near the surface of the sea.

It is an interesting fact that the Fish belonging to this one family have very different methods of feeding. The Cod and the Pollack both hunt their prey principally by day-light. The Pollack is guided by its sight alone, the Cod-fish is assisted by its barbel, which acts as a delicate feeler or organ of touch. The Hake, on the other hand, retires into deep water during the day-time, and only comes to the surface at night to feed. Similarly the Rockling hides away in holes or under stones during the day-time, and only comes out to hunt for the Crustaceans and little Fish upon which it feeds at night.

The development of these Fish presents some features of interest, as showing us the changes which occur in habit during their life history. The eggs of the Cod are buoyant, rising to the surface of the sea as soon as they are spawned. In twelve or fourteen days, according to the temperature of the water, the larvæ are hatched and swim about in large numbers just below the surface, feeding upon minute Crustaceans and other animals. A little later the young Cod frequently shelter themselves under large Jelly-fishes, feeding upon the numerous parasites which infest those creatures. When they are about a year old

they are found feeding among the sea-weeds on rocky coasts, and they migrate into deeper water when they reach their full size.

The John Dory is a remarkable Fish, by no means confined to the rocks, as its food often consists largely of Pilchards and Herrings. It differs from most of the Fish of similar habits in being remarkably flattened from side to side. This feature seems to be of service to it in the

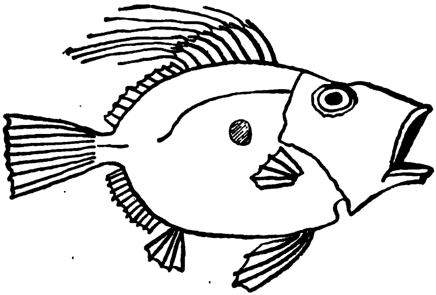


FIG. 18.—The John Dory.

peculiar manner it has of securing its prey. Mr. Cunningham, to whom we are indebted for this interesting observation, says:—"It does not overtake (its prey) by superior speed like the mackerel, nor lie in wait for it like the angler, but stalks it and approaches it by stealth. It is able to do this in consequence of the extreme thinness of its body, and the peculiar movement of its hinder dorsal and ventral fins. The dory places itself end on towards the fish it desires to devour, and in this position it is evident that it excites no alarm on the part of its prey. The appear-

ance of the dory seen in this way is a mere line in the water, to which no particular significance can be attached. I have not particularly noticed the effect of the ribbons of membrane, which project from the dorsal fin. But I have observed that the movements of the dory are very gradual except in turning; it alters the position of its body by a turn of the tail or side fins, and then slowly swims forward by vibrating the second dorsal and ventral, a movement which causes very slight disturbance in the water. The whole appearance of the dory in these actions is suggestive of suppressed excitement, his eyes being fixed on his prey."

We have now considered some of the chief features of animal life in the shallow seas, the illustrations being taken principally from the regions of English shores. The shallow waters of the tropics present us with so many phenomena of striking interest and importance, that the subject would be most incompletely treated if they were left out of consideration altogether, and, therefore, our next chapter will be devoted to them.

CHAPTER III.

SHALLOW-WATER FAUNA OF THE TROPICS.

THE shallow waters of the Tropical seas present us with so many different conditions of tides, of coast lines, of temperature, of liability to storms, and of other natural phenomena, that we find an infinite variety in the general character

of their Fauna. Just as on land, we find in one part of the Tropics a dense forest, and in another a dry desert, so in the Tropical seas we find on one coast a crowded population of animals and plants, and on another a sandy bottom, which is, comparatively speaking, lifeless. In order to bring before the reader some of the principal characters of animal life in the shallow waters of the Tropics it will be well to confine his attention to one part of the world which is fairly well known—namely, the Malay Archipelago—and refer only in passing to other localities. The most characteristic feature of Tropical coasts is the Coral-reef, and nowhere in the world may it be seen in more exquisite variety than in the archipelagoes of the East. Although, however, these vast structures are so abundant on some coasts, others seem to be entirely without them. They are not found at all on the Western coasts of America or of Africa, and even in some regions of the larger islands in the Pacific and the Indian Oceans, many miles of coast line may be devoid of them. These curious and interesting variations in the distribution of the reefs can be explained, but the explanation will be more easily understood when their general features have been described.

It is a well-known fact that the great masses of limestone which compose the reefs are formed by the activity of countless thousands of minute animals, but the popular idea of the general form of these animals has been very much misled by the unfortunate term "Coral insect," which has crept into many books of travel, and the leading articles in the newspapers. The word "insect" is used by zoologists as a general term for certain

air-breathing animals that are widely distributed over the surface of the earth. Many of them are extremely tiny, and hence the natural mistake has arisen in the untrained mind that all minute animals are insects. It might clear the ground a little if the reader would note at once that "insects" are very rarely indeed marine in habit. If there is a need for a popular word for the animals that form coral, it should be Coral "polyps" or Coral "anemones." The word "coral" has, from the zoologist's point of view, a very indefinite meaning, for it is applied to the hard skeleton of carbonate of lime formed by certain Sea-weeds, Sponges, and Worms, as well as to that of Coral-anemones and other Polyps. In many places on the British coasts the sea-bottom is very largely composed of a branching Coral formed by a true Sea-weed called *Lithothamnion*, and in other places very large lumps of rock are made by a Worm named *Filograna*. In the Tropical regions, too, the well-known Nullipores, which in many places play an important part in the formation of Coral-reefs, are of vegetable, and not animal origin.

However, the greatest part of the Coral-reef is made by animals closely related to the Sea-anemones, living together in colonies; and of all the different kinds of Coral-polyps, by far the most prolific as a reef-builder is one which will be referred to in these pages as the Madrepore.

Let us consider now the manner in which the Polyps form the Coral. In a very old work on the natural history of Corals a statement is made to the effect, that the Polyps construct the Coral in much the same way as Bees build their hive, or a Bird its nest. This very erroneous view coincides closely with ideas which might easily

be gained by a casual observation of corals in a museum. The lime is not, however, collected as such from the sea by the Coral-polyps and plastered round their bodies to form a house or shelter, but it is formed as a secretion by the activity of certain organs of the animal's body, and is consequently a true shell or skeleton. In a Coral, which is formed by a colony of numerous Polyps, the shell secreted by each individual fuses on to those formed by its neighbours, and thus a communal shell is formed which may assume a most complicated branching, bushy form, according to the species of the Coral and the conditions that are favourable or unfavourable to the nourishment and growth of the different parts of the colony. In such a Coral as the Madrepore every individual Polyp is connected with its neighbours by a system of branching canals; and as spaces are left for these when the shell is formed, the dried Coral is perforated by numerous tubular pores, and has a soft, spongy texture which can be easily crushed into a powder if trodden upon.

FIG. 19.—Polyp of a Madrepore Coral, showing the canals by which it is connected with its fellows.

In other Corals the canals of communication between the Polyps are entirely at the surface,

and the shell that is formed is much harder and imperforate. In others again colonies are not formed, but each individual grows to a considerable size and remains independent of its fellows all its life.

These, then, are three of the more important varieties of Corals found on the reef, the Perforate, the Imperforate, and the Solitary Corals; but it must be remembered that all the Corals of the reef cannot be included in these three groups. The varieties are much more numerous and in many cases much more complicated and difficult to understand.

Although the Coral-reefs of the Tropical world have a general resemblance to one another, the differences in detail are so great that it is impossible to describe any one as typical. In sailing over the edge of a reef near the coast on a calm day, when the water is so clear that the bottom can be seen at the depth of 8 or 9 feet, the reef may, in some regions, be observed to change in character every few minutes. In one spot there may be clumps of living Corals surrounded by beds of fine white sand; in another there will be great stretches of branching Madrepores; in another Madrepores, Mushroom-corals, the Imperforate Brain-corals, Sponges, and many other forms of life will be clustered together; while further on the predominant features will be the soft and slimy Sarcophytums, looking like large green toad-stools, some lumps of Organ-pipe Corals and a few colonies of the Blue-coral.

On other coasts I have wandered for miles along a reef mainly composed of endless tangles of Madrepores, with very little variation indeed in the general form of the Corals, in the character

of the Sponges and Sea-weeds that grow with them, in their colour or in any other detail. Any-one reading the many accounts of Coral-reefs that have been written by travellers, must be struck with their inconsistency as regards many particulars; and in no one point are they more inconsistent than in the description of the colours—some writing in glowing terms of the beauties of the sea-gardens, and others complaining that their charms have been grossly exaggerated. As a matter of fact some reefs have a prevailing dull green or brown tone, while others exhibit all the colours of the rainbow in their more brilliant shades and tints. Another cause of the discrepancy is that some reefs can only rarely be approached in a small boat owing to the breakers that dash over them; whilst in the Tropical calms a tiny canoe can with perfect safety be manœuvred over the reefs during nine months of the year. From my own experience I can assert that it would be difficult indeed to exaggerate the glorious beauty of some of the reefs in the Malay Archipelago, more particularly of those where many different kinds of Corals may be seen in close proximity to one another. On such a reef, for example, there may be seen Madrepores with bright violet growing-points to their branches, orange or red Fan-Corals, bright brick-red Sponges, yellow Sarcophytums, emerald green Organ-pipe Corals and dozens of other forms of animal life in every imaginable colour. When seen from a boat through two or three feet of water, these portions of the reef look more like a beautifully planted flower-bed than a mass of animals; but the simile is not a complete one, for the branches of the Madrepores, the great knobs and

lumps of the Brain and Organ-pipe corals, the fronds of the Gorgonias and other forms make a wild mass of organisms resembling a tangled thicket or a miniature forest. At low water of spring-tides the living reef is partly left exposed, and then the scene changes, for the Polyps retract their tentacles after the manner of the Sea-anemones and retreat as far as possible into the shelter afforded by their shells.

The interest of the living reefs is, however, by no means confined to such organisms as the Corals

FIG. 20.—Chætodon.

and Sponges, which are immovably fixed to the bottom; for numerous brightly-coloured Star-fishes, Sea-urchins, Brittle-stars, Sea-slugs, and their allies crawl about among the branches and the débris of the dead Corals; while Crabs, Lobsters, and Shrimps of many kinds may be seen swimming or crawling in search of their prey, and the marvellously striped and spotted Coral

fishes dart hither and thither in the thicket, or remain hovering in the water among the Corals. The whole scene is most fascinating. As the boat slowly drifts along, new and strange creatures are constantly coming into sight and disappearing again. Here the writhing arms of a bright-blue Brittle-star may be seen embracing the stem of a Coral-branch; there a curiously flattened Chæto-don, with its body marked by great diagonal yellow bands, is nibbling at the young, tende-branchlets; in another place four or five Sea-urchins with very long and slender spines are lying apparently motionless on the bottom; while a little further on a long black Slug-like creature, the famous "Trepang" of commerce, is slowly wending its way across the reef. Now and again a large shoal of little Fish or a small party of Cuttlefishes may be seen, and these may rapidly be dispersed in all directions by the sudden dash of a Sea-perch or a small Shark. The interest is so varied, so many-sided, in these scenes of animal life that the attention of the naturalist is with difficulty kept to any particular point. The feature which is perhaps the most striking is, however, the wonderful variety in the colours of the animals and of the character of their markings.

If we consider the Fishes alone, we find some of them have broad yellow bands running diagonally across their bodies, others have thin longitudinal stripes of blue and yellow, some have a uniform bright-red colour, and others again have their red skins speckled with blue spots. It would take more than a whole chapter of this book to describe even the principal varieties of pattern found on one such Coral-reef, but the

main fact that has to be related is that where the reefs are built by brightly coloured Polyps, there we find these curiously marked Fishes. There can be little doubt that the marking and colouring do give a certain amount of protection to them. Numerous individual cases have been mentioned of Fishes which resemble some particular Sea-weed or Coral; but this general statement is the important one, that on a parti-coloured background the striped and speckled Fish are less conspicuous than those that are modestly attired.

The Fishes of the reefs, however, have other means of protection than that afforded by their colours. The Trigger-fish and Coffer-fish, for instance, have a body encased in closely fitting hard, thick scales, so that they might almost be called "armour-plated fish"; and the Globe-fish bristle all over with long and extremely sharp spines. In the Trigger-fish there is a curious modification of the three front spines on the back, to which their name is due. It is not known precisely how they act, but they probably form an effective weapon of defence. In the same family of Fish we frequently find on each side of the tail two or three rows of sharp spines, which may also be regarded as defensive. In the family of the Sturgeons there is only one of these spines on each side of the tail, and it is much larger than any of those in the Trigger-fish, and capable of being folded down into a case in the skin like a clasp-knife. It is said that these spines are connected with a poison-gland, and can give very severe and painful wounds, like the poison spines of the European Sting-rays and Weavers.

A few days' hunting on a Coral-reef will reveal the fact that it supports a very considerable population of Crustaceans. They are not at all obvious at first to one who has had no previous experience of reef-work, partly because they resemble the general appearance of their surroundings very closely, and partly because of their habit of remaining perfectly motionless when first

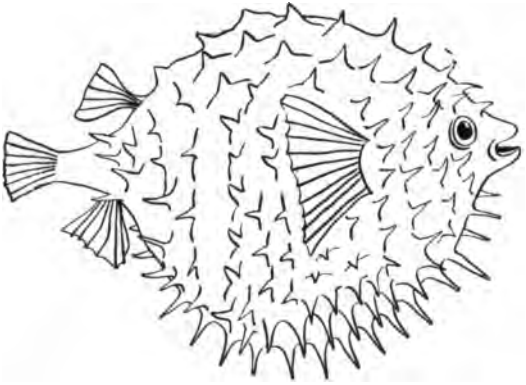


FIG. 21.—Globe-fish.

alarmed. In form, many of them are like the Lobsters, Crabs and Prawns of our own coasts, but their colours and markings are, like those of the reef-fishes, characterised by their brilliancy and their arrangement in bands and stripes. The smaller ones can be caught after a little practice with a simple hand-net, but the larger ones are more easily captured by a rattan noose in the pools, after the blocks of Coral are loosened by a pick-axe and slowly turned over.

The Coral-reef is a favourite hunting-ground for the conchologist, some of the largest and most beautiful shells in the world being found amongst the Corals. In Celebes, the giant bivalves, the huge Tridacnas, which are sometimes two feet across, and whose shells have been known to weigh as much as 500 lbs., may be seen wedged in among the Corals. The mantle of the living animal presents to the observer a wonderful display of colour as it lies in the shallow water with its shells open. The animal is eaten by the Malays, who roast it on a tripod spit over a fire, and cut it into steaks. A fair-sized Tridacna will afford a good meal for four or five men. The great Cowries, Helmet-shells, and many other species may be found in hunting over the reefs, but their beauties are frequently hidden, when alive, by the coal-black mantle which folds back over the shell as they crawl along. It must not be supposed, however, that all the shells of the reefs reach to such enormous size as those we have hitherto mentioned, for a rich harvest of species awaits the eager conchologist who hunts for the smallest shells he can find in the pools. Within the last few years a large number of new species of small Molluscs have been described from the coral seas, many of which do not attain to a total length of more than $\frac{1}{8}$ of an inch when perfectly adult, so that the range in size of this class of animals is very great indeed.

So much has been said about the Madrepores, the Imperforate Corals and the solitary Corals of the reef, that the impression might be left that all the Polyps of the Tropics differ from those of the Temperate regions in the fact that they form shells or skeletal structures. This is by no means

T. L. Hawkinson

March 18 - 1910.

the case, for there are many species of true Sea-anemones and other Polyps to be found on Coral-reefs which make no shell at all, and others in which the body-wall is strengthened by numerous but very minute spicules or grains of lime which, on the decomposition of the animal's body, fall down into a shapeless powder or sand.

True Sea-anemones are not very abundant on the reefs of North Celebes, but many species have been found on the Barrier-reef of the Australian coast, and among them specimens reaching the gigantic size of two feet in diameter—the largest size attained by single individuals of the class of animals to which the Anemones belong. Another family of Polyps called the Clavulariidæ belonging to the Alcyonarians has some species which make no skeleton of calcium carbonate. An illustration of one of these is given below (Fig. 22).

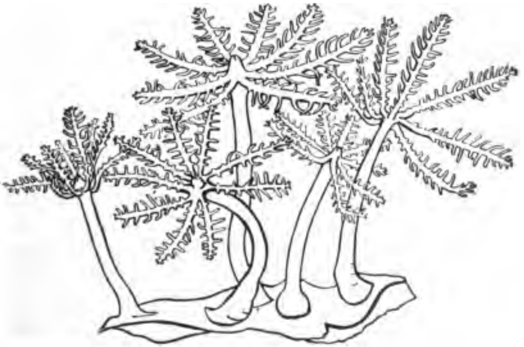


FIG. 22.—Stereosoma, one of the Clavulariidæ.

Another species, called *Clavularia viridis*, which forms a few spicules in its body-wall, has a very

wide distribution in the East Indies. In some places patches of it may be seen several square yards in extent, and the crowds of little Polyp heads with their eight-feathered tentacles waving to and fro with the pulsations of the tide, is a sight that excites immense interest and admiration in the mind of the observer.

One word more about the Corals. Where they are so abundant in number and species, where rocks hundreds of miles in extent are mainly composed of their shells and skeletons, it might be thought that a rich profit could be gained by collecting ship-loads of the Coral that is used for making beads and brooches by our jewellers. Any expedition, however, fitted out for this purpose would end in disastrous failure, for the Precious-coral is not known to occur anywhere in the neighbourhood of Coral-reefs, but the fishery is confined to certain parts of the Mediterranean Sea. Species closely allied to the Precious-coral, but of an inferior colour, have been found in the Japanese waters. None of the Coral structures found on the reefs have the same delicate salmon-pink colour and probably none of them are hard enough to take a good polish.

The Coral-reefs which occur in different parts of the Tropical world were considered by Darwin under three heads,—Barrier-reefs, Atolls, and Fringing-reefs. The distinction between these three kinds of reef is not one that can be insisted upon scientifically, but the arrangement is convenient for purposes of description.

The Barrier-reefs (Fig. 23, *B*) are situated at a distance of one to eight miles from the coast, and are separated from it by a lagoon of moderately deep water. The Barrier-reef of New Caledonia

is said to be 400 miles in length, and it follows the general contour of the coast-line.

The Atolls (Fig. 23, *C*) are ring-shaped islands composed of coral limestone with a lagoon of salt water within them, situated in the sea without any definite relation to other existing land.

The Fringing or shore-reefs (Fig. 23, *A*) are situated at a distance of 100 yards or less from

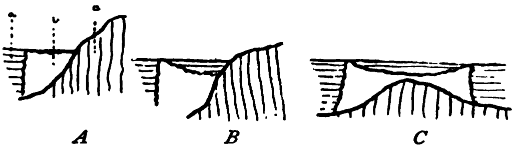


FIG. 23.—Fringing-reef, *A*; Barrier-reef, *B*; Atoll, *C*. *a*, sea; *b*, reef; *c*, rocks of the coast.

the beach and separated from it by a shallow lagoon which is frequently left as a dry sand-bank at low tides.

Many forms of reefs are found in different parts of the world, but they may all be looked upon as special modifications of one of these three groups. The facts which Darwin collected about Coral-reefs in his memorable voyage round the world in the *Beagle*, suggested to this great observer that all the different forms of reef must be related to one another, and he formulated an ingenious theory to show how, by the gradual sinking of the crust of the earth, Fringing-reefs may have become, in the course of a long period of time, either Atolls or Barrier-reefs. Some doubts have recently been expressed as to the truth of Darwin's famous "subsidence theory." But, whether it is true or not, to Darwin is due the credit of bringing home forcibly to our minds the fact that

Coral-reefs are slowly undergoing changes of growth and of destruction, which must lead to most important and far-reaching alteration in the character of the Tropical seas. It is not intended in this work to enter into a discussion of the various alternative theories of Coral-reef formation, but a few words may be added on the method of formation of Coral limestone.

In studying any one particular form of reef-building Coral we can find a long series of specimens from one inch in length up to a certain maximum, which varies with the species and the reef, but may reach over five feet in diameter as can be seen in the specimens now in the British Museum at South Kensington. Beyond this maximum size—let us say four feet in diameter—the Coral rarely grows, because at a certain age, probably when the vitality of the Coral is on the wane, the stalk of attachment becomes so bored with parasitic Sponges, Worms, Fungi and other organisms, that it is thoroughly rotten. If a large block be picked up from the reef, and with the help of two or three strong natives carried ashore and broken up with a hammer, a most interesting migration of Crabs, Worms and other creatures occurs, and the collecting bottles may be filled with a rich variety of animals parasitic on the Coral. Now the time comes when the stalk becomes so brittle that a heavy wave breaks it in two, and the Coral topples over and dies. If it falls into the sand, either on the inside or the outside of the reef and becomes buried, it may be preserved fairly complete, but if it lodges between other Corals the waves and the parasites between them dissolve it and break it up into thousands of pieces. This constant disintegration leads to the formation

of great quantities of coralline sand which fills up the interstices between the living Corals, or gets washed over into the lagoon, or falls as a talus over the sea-ward slope of the reefs. In the latter case lumps of Coral torn off from the reef become embedded in it and form with it a bank which gives support to more living Polyps on the sea-ward slope. Consequently, in the course of many years, a reef which was at one time only fifty yards from the beach may have extended to a distance of a hundred yards or more, growing, as it were, on the skeletons or shells of the Corals that have died. There can be little doubt that Coral-reefs do grow sea-wards in this manner in some places, but they may also be either beaten back or kept for a long time perfectly stationary if the tides are too strong or too slack.

What the precise conditions are which favour the growth sea-wards of Coral-reefs has not yet been systematically investigated; but we may suppose that if the tides are too strong the sand has no opportunity of settling between the Coral blocks and forming a solid limestone rock, and if they are too slow the Coral-polyps do not get sufficient nourishment to allow them to build fast enough to counteract the solvent action of the water.

An interesting point connected with the Coral-reefs is the manner in which they are formed at first. A volcanic upheaval gives rise to a new island which, in the course of time, is surrounded by a Fringing-reef. How does this reef begin?

The answer to this question has been recently given by the observation of the formation of new Corals on the shores of the island of Krakatoa which is situated in the Sunda straits, and was the seat in 1884 of one of the most violent volcanic

eruptions of historical times. After the eruption the sea-bottom round the island was found to consist of a fine volcanic mud, in which it may be believed no Coral embryos could find a secure foothold. Now it is known that living Corals give rise to a number of very minute larvæ which for a period of time swim freely in the water, eventually settling down on some solid stone or shell to give rise by growth and budding to the Coral blocks. These larvæ frequently settle down on a piece of floating pumice-stone and after a time grow to such a size that they sink it. If, in sinking, they fall upon the bottom in shallow water they form together a substratum on which other larvæ can settle and flourish. This is apparently the manner in which Coral clumps are beginning on the slopes of Krakatoa and these will undoubtedly give rise in time to a more or less complete Fringing-reef.

Any further discussion on this point would lead us into subjects beyond the scope of this book, but enough has been said to indicate to the reader the manner in which the countless Coral-polyps may, in the course of time, change the position of the reefs on Coral shores, thereby altering the set of the tides there, changing the position of the sandbanks, affecting the rate of erosion of the cliffs, and in other ways causing important modifications of the coast-line.

I have mentioned that the ground on the growing edge of the Coral-reef is carpeted with Corals, Sponges, and many other forms of animal life; in the water swim countless Fish, and the branches of the Corals yield to the naturalist innumerable forms of creeping and crawling creatures. The shallow waters of the Tropics, as a whole, how-

ever, do not possess a particularly rich Fauna,—in fact, the distinguished Dr. Kükenthal, who has had great experience in marine work, says that, in his opinion, the Tropical seas are not richer in littoral animals than the Arctic seas. Between the reef and the sea-beach there is a lagoon, of varying breadth, with a sandy bottom, which is almost as barren of animal life as a desert. A few Worms and Crabs, here and there a Star-fish and some shells of Foraminifers, are all the spoils which fall to the bag of the naturalist after many hours' wading on this unprofitable ground. The reason for this is, perhaps, not far to seek. When the tide goes down many stretches of sand are left dry, and others retain only a few inches of water. The exposure to the heat of a Tropical sun soon kills and dries up any living animal that is unable to burrow deeply in the sand, and the water in the shallow pools rises in temperature to a degree that the human hand or foot can only just bear, so that the little Fish that escape into them run the risk of being slowly cooked alive.

On the inside of the lagoon there is, in many places, a broad belt of Mangrove trees, forming the "Mangrove-swamp," which contains some interesting and important animals. These trees have a peculiar spreading and branching system of roots which are left exposed when the tide goes down, and form with one another a kind of network or web a foot or more above the ground, upon which it is possible, with care, to walk from place to place, at low tide. Between the roots there is a slimy black sand or ooze, sometimes hard enough to walk upon, but more commonly soft and treacherous. At high tide the water rises to a height of two or three feet, completely cover-

ing the roots and giving the swamp the appearance of a forest growing in the sea. Of the animals, aërial and terrestrial, that haunt the swamps it is not necessary to say more than a few words, although they too form a study of great interest to the enthusiastic naturalist. But the marine zoologist who visits the swamps cannot fail to take note of the millions of Ants, Flies and Mosquitoes which torment him at every step, and make a prolonged stay an impossibility.

One of the first creatures to be seen on entering a Mangrove-swamp at low tide is a curious little Fish called *Periophthalmus*. In some places

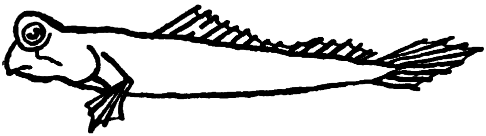


FIG. 24.—Periophthalmus.

hundreds may be seen at one time resting on the roots of the Mangroves, or skipping over the pools of water from one root to another. There are many varieties of *Periophthalmus* in different parts of the world, and their habits are not exactly the same, so, to give an accurate description, our attention will be confined to the form occurring in N. Celebes. This little Fish is about three inches in length and remarkable for its very peculiar eyes, which are of a bright yellow colour, situated quite close together on the top of the head, and projecting so much from their sockets that the outline of more than two-thirds of the eye-ball can be seen. These eyes are extraordinarily movable, and frequently revolve quite in-

dependently of one another, like the eyes of a Chamæleon, giving the animal a most grotesque and even ludicrous expression. These Fish seem to swim in the water very seldom; when undisturbed they may be seen clinging to rocks or trees by their fore-fins with their tails only in the water, but from time to time they spring into the air to catch a Fly on the wing, or dive for a small Crab which has come unwarily within their range. Their fore-fins are peculiarly adapted to their habits, in that they have a very muscular base and a distinct elbow joint.

These creatures are not easy to capture, as the ground on which they live is not adapted for rapid pursuit, and it is impossible to get close enough to them to catch them in a hand-net with a long handle. When kept in an aquarium it is seen that although they are rapid swimmers when they do go below the surface, they seem to prefer to live with their head and shoulders out of the water; and when chased in their natural haunts they very rarely, if ever, seek to escape by plunging into the water, but they execute a series of rapid jumps with extraordinary rapidity from root to root or rock to rock, and so avoid their pursuers. Their existence is really an amphibious one, and their food consists partly of Insects on the wing. Their gills are very much reduced in size, and it seems probable, from observations that have been recently made, that their respiration is partly carried on by the thin skin between the rays of the tail-fin.

Another animal extremely abundant in the Mangrove-swamps of Celebes, and, like *Periophthalmus*, having a very wide distribution in similar places in other tropical countries, is the

"Caller-crab" *Gelasimus.* These Crabs are about an inch in breadth across the back, and are remarkable for possessing one very much enlarged and brightly-coloured claw, the others being normal in size and dull in colour like the rest of the body. On first entering the swamp at low tide there may be seen on the mud between the roots of the trees a number of bright yellow, blue or green objects, which, as the traveller approaches, disappear one by one into holes in the ground. When the eyes are accustomed to the gloom of the swamp these bright objects are seen to be the great claws of the "Caller-crabs," the rest of the body being inconspicuous owing to its close resemblance in colour to the slimy ground.

These are the principal and most abundant marine inhabitants of the swamps, and as has been pointed out, all of them are more or less amphibious in habit. More locally distributed, Oysters and other bivalves may be found attached to the roots of the trees. Several species of marsh Gastropods occur, some of them in great abundance in a few localities. Occasionally a Sea-anemone, with remarkable powers of burrowing rapidly in the sand when disturbed, may be found, and to the microscopist a harvest of Foraminifers and other minute forms of life awaits investigation and description in the Mangrove-swamp.

Whenever the tide is high a considerable number of Fish-fry, Jelly-fish, and other forms of floating and swimming life characteristic of these waters, drift into the swamps; and some being caught by the tangle of roots are left behind, either in the pools, or high and moderately dry upon the sand when the tide ebbs. Upon these victims of the

retreating tide swarms of Ants and Flies descend from the trees, Crabs from the shore and from their holes in the sand are on the watch for them, Kingfishers and Sandpipers are ready to pounce upon those which are most to their taste, so that before the friendly waters of the ocean return to the swamp, scarcely one of them is left.

These constitute what may be called in the swamp the *extraneous* Fauna, which if it is not truly indigenous is nevertheless necessary for the continued existence and well-being of the true inhabitants.

The character of the sea-bottom on the outer side of the living Coral-reefs varies so much in different parts of the world that an adequate treatment of the Fauna in that region would have to be one of greater length than is possible in this book.

The living edge of the Coral-reef is in some cases situated on the top of a submarine precipice of very considerable height, and in many places the sounding-line goes down to a depth of five or six hundred feet a few yards beyond the limits of the reef. The practical difficulties in the way of determining the character of the Fauna of any sea-bottom that shelves in this manner are very great, but where it is partly composed of massive lumps of solid Coral they are at present insurmountable. Every time the dredge or trawl reaches the bottom it becomes entangled in the Coral branches, and is liable to be seriously torn, or even lost. Swabs and iron hooks and fish traps may yield some scraps of information, but speaking generally, the Fauna of these steep slopes is scarcely known at all.

The most important question, from the geo-

logical point of view, that has to be determined is the depth of water in which reef-building Corals can live and thrive. This is still a matter of uncertainty owing to the practical difficulties met with in the attempts to investigate it. Darwin estimated that the limit of vigorous coral growth was between 20 and 30 fathoms, but in recent years, owing to the discovery of luxurious Coral patches in 44 fathoms on the Tizard and Macclesfield banks, there is a pretty general opinion that his estimate is too low.

Whatever the exact limit may be, it is quite clear that in many parts of the world the sea-bottom quite close to the outer edge of the reef cannot support a vigorous Coral fauna. Here and there patches of peculiar deep-sea species of Corals occur, but they do not form in such depths anything of the nature of a reef. They are usually isolated specimens, similar to those that are found in deep water on the Norwegian coast and other parts of the world outside the limits of the Tropics; but these specimens really belong to the deep-sea Fauna, of which we shall learn more in another chapter.

In many places, however, the water at the base of the outer edge of the reef is not very deep, and may slope away gradually towards the bed of the ocean. The Fauna of such slopes in the Tropics is not characteristically rich, as my own experiences of dredging in such waters have proved. Time after time the dredge that was used in 15 to 20 fathoms off the coast of Talisse, came up with nothing but sand or gravel. Occasionally a Brittle-star or a branch of dead Coral, with a few Zoophytes growing on it, came up; and in some places a few beautiful Lily-

stars or Crinoids relieved the monotony of the investigation. But, on the whole, the animals found in this region were not numerous, nor of a character to excite any particular interest.

Before bringing this chapter to a close, a brief reference must be made to one of the most remarkable phenomena in the animal kingdom,—this is the history of the Palolo worm. On certain parts of the coast of the Samoan islands the Palolo worm appears in great abundance in the early morning hours of one or two days at the beginning of the third quarter of the moon in the months of October and November. As the worm is regarded as a very great delicacy by the natives, the day of its appearance is looked upon as one of the most important red-letter days of the year. Weeks before the worms are expected the advent of the Palolo is discussed, stories are told of the fisheries of by-gone years, anecdotes of the last year are remembered and rehearsed, and the whole population is prepared for the great event as for a feast.

When the grand day arrives the boats are decorated, the girls put on all their finery, and everyone who can find a seat in a boat goes off to the fishery amid a merry chorus of song and laughter. It must, indeed, be a strange sight to see the flotilla of canoes with their eagerly expectant and gaily-bedecked crews, waiting in the dim light of the half moon for the day to break and the exciting fishery to begin. As soon as it is light enough to see into the water, a few writhing Worms may be distinguished at the surface, which increase in number with such extraordinary rapidity, that in a little while it is impossible to see anything below three or four inches owing to

the multitude of Palolos. As quickly as possible the fishery proceeds, every man, woman, and child gathering the harvest of Worms during the precious moments of the sunrise. When at last the sun rises well above the horizon the Worm disappears again, and the boats hasten to the shores with their booty.

This remarkable swarming process of the Palolo, occurring as it does, only once or twice a year, in constant relation with a particular phase of the moon, and lasting on each occasion only a few minutes in time, is not the only noteworthy feature of the animal.

The Palolo worm, as it is caught, varies in length from an inch to a foot or more, and is about a quarter of an inch in breadth, but it readily breaks up into pieces when handled. It is composed of numerous rings or segments, each provided with a pair of processes bearing bristles, but there is no head. Astonishing as it may seem to those unacquainted with the natural history of Worms, it is nevertheless a fact that when the Palolo swarms it leaves its head behind among the Corals, where, in all probability, it regenerates a new body. This accounts for the fact that while the body of the Palolo is frequently brought to Museums in England and America, its head is a rarity. The colour of the Worm varies very considerably. The pieces bearing eggs are usually of some shade of green, hence the specific name *Palolo viridis* that is given to it by scientists, but the males are usually white. In connection with the appearance of the Worm there is a curious statement that once in every four years it is exactly one lunar month late, so that the time of year of its occurrence is constant. The natives

are also forewarned of the advent of the Palolo worm by the movements of the land Crabs, which, it is reported, come down from the fields and forest a few days before the Palolo feast and plunge into the sea.

The precise habitat of the Worm when it is not swarming is still a matter of some doubt. A few rare specimens have been found in the Coral blocks in shallow water, but it is generally supposed that the majority of them live in deep water on the outer side of the reefs. It is not confined by any means to Samoa. It occurs also in Fiji, Tonga and other Pacific islands. A Worm similar to the Palolo in habits was described years ago by Rumphius in the Malay Archipelago, and Saville Kent mentions a little Nereid worm with similar spawning habits on the great Barrier-reef of Queensland.

CHAPTER IV.

SURFACE-SWIMMING FAUNA (INVERTEBRATES).

EVERYONE of an observant turn of mind must have noticed that in the wake of a boat that is passing through the water on a calm summer's night, sparks of bright phosphorescent light may be seen to appear, to remain for a few seconds, and then become extinguished again. Sometimes the breaking of the ripples on the surface of the water seems to be sufficient to cause these sparks to appear, but occasionally streaks and flashes of pale blue light arise and disappear without apparently any such mechanical disturbance.

The phosphorescence of the sea, as this phenomenon is called, is common enough on our coasts, but it never reaches the degree of brilliancy and beauty which is so remarkable in the open Atlantic Ocean, the South Seas, and some other parts of the world. In the Atlantic Ocean the phosphorescence is sometimes so bright that it is possible to read a book on deck by its light alone; and on a dark night in the Banda seas the water is often like a huge expanse of pale blue smoke studded with diamonds and other lustrous gems.

These lights are mainly produced by animals which float and drift about on the surface of the water. It is not, as is very commonly supposed, only one or two different kinds of animals that are phosphorescent, but a vast number belonging to many widely different families and of a great variety of form and structure. When the day breaks many of these animals sink down a few fathoms into the darker and cooler strata of water, but a considerable number remain so close to the surface that they can be easily caught in a muslin net dragged after a boat.

Some of these animals, such as the Jelly-fish, can, during the day, be observed clearly enough from the boat, others can only be seen when the contents of the net are emptied into a glass bottle, and others again are so minute that it requires a strong magnifying glass to detect them at all. Such animals that float or drift in the water without powers of swimming vigorously in one direction or the other, are collectively called the Plankton. In every sea, from the Arctic regions to the Equator, a Plankton will be found. Sometimes it is mainly composed of one species, in other cases it consists of many different species

living together. Under certain conditions the water is simply crowded with these organisms, and in different circumstances the Plankton is represented by only a few individuals.

The variations of the Plankton in different parts of the world have, of recent years, been subjected to many searching investigations, but although many important facts have been recorded, the explanation of the principal phenomena remains a mystery.

One of the most interesting facts, perhaps, is the extraordinary local variations to be observed. To give a single example as an illustration of this point the case of the common white Jelly-fish may be mentioned. On occasions the surface of the water in bays and estuaries contains so many of these animals that the sea appears to be little more than a mass of jelly. In other seasons not more than a few isolated individuals will be seen all through the summer months.

With all the resources of modern scientific investigation no adequate explanation has been given to account for this fact. It may be that the variation is due to the prevailing winds or tides, to the temperature of the water, to the roughness or smoothness of the sea, to disturbance of the ground where the eggs have settled, or to some other hitherto unforeseen conditions. Not only seasonal, however, but even diurnal variations occur, of a most remarkable and inexplicable character.

On one occasion for example I was collecting a number of Jelly-fish in Southampton Water, and for nearly two hours specimens were obtained as fast as they could be hauled into the boat. Suddenly a change came, and in a few

moments the water that had been alive with these animals seemed to contain not one. Another time, after dredging nearly all the afternoon at Lulworth for *Hormiphora*, with the very poor success of a half dozen specimens, the net came up simply choked full of these little round jelly-like Ctenophores, and for the remaining hours of dayl'ght there appeared to be an abundance of them all along the coast. One morning in the Tropics, at about an hour after sunrise, I was looking over the side of a steamboat, and saw that the surface waters were full of beautiful and rare species of floating animals. In less than half an hour afterwards, when a boat was put off, scarcely one of them could be found. Anybody who is accustomed to working with a tow-net can give similar experiences.

In each of these cases a simple explanation might be suggested. In the first case it might have been the change in the tide which effected the disappearance of the Jelly-fish; in the second it might have been the approach of nightfall that caused the Hormiphoras to rise; and in the last case it might have been the approach of the heat of day; but when carefully considered such explanations are not sufficient, in that they do not account for the suddenness of the change.

The fact is that the conditions of life in the surface waters are so complicated that it is extremely difficult for us to accurately estimate the balance of the forces which act upon these organisms. The direct heat of the sun, the light of both the sun and the moon, the tranquillity or roughness of the sea, the conditions of the tides and winds which cause changes in the surface temperature of the water, independently of the

direct heat of the sun, all influence the delicate tissues of which these animals' bodies are composed, and cause them to change their position.

The animals which compose the surface Plankton may be considered under two heads—those that are adult, and those that are the larvæ of sessile and crawling forms of life which in the adult stage live at the bottom.

Those belonging to the former group frequently occur far out in the open ocean as well as in the neighbourhood of the land, and have as a rule a wide geographical distribution. Those belonging to the latter group are more usually found within a few miles of the coast line, although winds and tides may occasionally drift them far out into the sea, where their larval existence is prolonged for an abnormally long time. Leaving out of consideration for the moment the many interesting exceptions, we may say that the Plankton of the open oceans differs from that of the neighbourhood of the coasts, by the larger proportion of adult forms that it bears.

A great variety of animals pass the whole of their lives in the surface waters of the sea, but the commonest and most widely distributed of all probably are the Copepods belonging to the class *Crustacea.*

The Copepods are minute creatures, rarely exceeding a quarter of an inch in length, which row themselves through the water by a pair of long antennæ, projecting from the head end of the body. They occur in fresh water as well as in the sea, and so abundant are they that if a glass tumbler be filled with the water from a pond, a lake, or the sea, and examined with a magnifying glass, a number of specimens are almost sure to

be seen. They occur in abundance at the surface of the sea in nearly all climes, and very often are the sole representatives of the Plankton that are found in the hauls of the tow-net.

Attention has already been called above to the fact that in the Tropics the surface-floating animals gradually sink down into the depths as the heat of the day approaches, but even on fine calm days a few Copepods will be found at the surface. Although they sometimes occur in Temperate seas in such vast numbers that the water is quite discoloured with them, more variety of form, or, in other words, more distinct genera and species are found in the warm and Tropical parts of the world.

The study of this group reveals to the microscopist some of the most marvellously beautiful displays of colour and form that can be found in the animal kingdom. Sometimes the body and legs are beset with an immense number of extremely fine and delicate spines, which are in some cases provided with rows of still finer spinelets, giving them the appearance of a most minute feather. Sometimes the body contains large granules of a bright-red colour, and at others smaller granules of a bright blue are seen scattered among the organs. The female Copepods usually carry, securely fastened to their tails, two little pear-shaped sacks of eggs, which are sometimes bright green, blue or red.

Endless are the varieties of form and colour presented by these little creatures, and endless are the beauties which the study of their structure reveals; but as we have mentioned them first as inhabitants of the surface waters of the seas, we must pause to consider here how these

organisms, which excite so much wonder and admiration, are adapted or fitted for their peculiar mode of life. But it must be remarked that these statements apply only to the free-swimming Copepods, for many animals classed in this group by

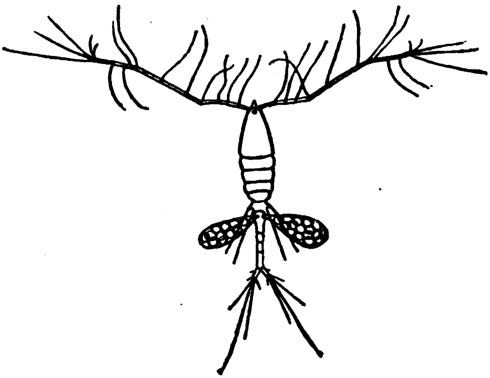


FIG. 25.—A free-swimming Copepod.

zoologists are parasites, and as such are so profoundly changed that they might at first sight be relegated to another class of organisms altogether (see p. 161).

Now we must remember that animals that live in the surface waters must be prepared to keep afloat for the whole period of their lives—from the time they are hatched until they fall a prey to some voracious enemy. Under ordinary circumstances, they never find an opportunity of resting, either on the sea-bottom or on any floating substance.

If a Copepod is watched in a tumbler of water

it will be seen to give a number of strokes with its long antennæ and then to rest suspended for a few seconds; a few more strokes follow and then another pause, and so on. During the period of rest the body sinks slowly, sometimes almost imperceptibly, but never so much that it cannot recover its position in the water after the first few strokes.

It must be clear to the reader that the less it sinks during the pause the less will be the muscular activity required to regain its position, and that, consequently, every mechanical contrivance that its body possesses to diminish its tendency to sink will be a saving of muscular and nervous energy.

A very simple experiment will demonstrate that a body which presents a considerable surface to the water, sinks more slowly than one of the same weight that is round and compact. If we take two equal pieces of silver paper and roll one of them into a tight little ball, leaving the other as a flat sheet, and then let them sink together in a tall jar of water, the former will reach the bottom long before the latter. Similarly the body of an animal which possesses a dense armature of spines, as it presents more surface to the water, sinks much more slowly than the body of an animal of the same weight that is smooth and compact.

The spininess or hairiness of the Copepod body, then, may be regarded as one of its adaptations to the environment in which it lives. But of course this character is not by any means confined to the Copepods. Very many of the surface-swimming Crustaceans, and more particularly their larvæ, have remarkably spiny bodies, and

among many of the Foraminifers, Radiolarians, Worms, Molluscs and even Fish we find some similar extension of the surface of the body which lowers the sinking rate. Another means by which the bodies of many of the animals composing the Plankton are buoyed up, is the secretion into a special chamber or reservoir of some gas or oil of a lesser weight than the sea-water. This is what may be called the balloon principle. In such animals we may regard the heavy muscles, skeleton, skin and viscera as the car and the freight of the balloon, while the gas reservoir corresponds to the whole silk case containing the coal-gas.

Such an animal might also be compared to a man in the sea clinging to an india-rubber life-belt. The bodv of the man by itself is heavier than the water, and in the absence of the muscular exercise of swimming sinks rapidly to the bottom; but the body of the man and the life-belt taken together are lighter than water and float continuously without any action of the muscles. If the life-belt were considerably smaller than usual the man and belt would sink, but much less rapidly than the man alone; and the muscular energy required to keep himself afloat would be far less with the belt than without it, consequently he would be able to keep afloat much longer with the same expenditure of muscular energy. The bodies of many of these surface-swimming animals may then be best compared with a man assisted by a *small* life-belt. When dead or still they slowly sink, but a slight amount of muscular energy expended in swimming is sufficient to keep them afloat. In what has been said above about the body of the Cope-

pod, reference has been made to certain bright red granules. These are in all probability little globules of some oily or fatty substance lighter in weight than the sea-water, which serve to buoy up the body of the little creature. It is difficult to say why they should have such bright colours. We have no record of observations that show that the colours can be of any use to them as a protection from their enemies, nor is there any physical explanation of the colours of these granules any more than of the blood, the bile and other products of animal and vegetable vital processes. The eggs contained in the egg-sacks of the Copepods also bear a certain amount of oily substance very frequently different in colour from that of the other parts of the body, and this probably acts in the same manner upon the body of the parent or on that of the little larvæ when they are first hatched.

Thus we find in the body of the Copepods at least two important modifications of structure, which render them fit or suitable for their life-long swim in the surface waters of the sea.

Let us now consider another important group that has the same habit but differs from the Copepods in size and form, namely, the Jelly-fish.

The Jelly-fish, or Medusæ, as they are usually called by zoologists, are disc or bell-shaped animals of a very soft gelatinous texture. From the centre of the disc or bell there hangs down a tube of varying length bearing the mouth, and the margin is often provided with a row of thin delicate tentacles like a fringe. (See Fig. 7.) When watched on a calm summer's evening they may be seen to slowly sink a few inches or more from the surface, and then with a series of convulsive

contractions of the bell to rise to the surface again. Sometimes these contractions may be observed to continue perfectly rhythmically for a long time.

In one of the commonest of the English Medusæ four rings of a bright pink or orange colour may be observed in the disc. These are eggs and male spawn, and when shed they give rise to multitudes of tiny little larvæ which sink to the bottom and become fixed to some rock or sea-weed. After the larva has securely fixed itself it becomes changed into a little Polyp which gives rise, in the course of time, to a number of small discs, arranged one above another like a pile of saucers. These discs break away from the base and from the parent stock to grow into the form and size of the adult Jelly-fish.

We have here an example in the life-history of the common Jelly-fish, of what is known as "alternation of generations." The eggs give rise to sessile Polyps, and these produce a number of buds which, when fully grown, give rise in their turn to the eggs; or, in other words, the egg-producing generation of large surface-swimming Jelly-fish regularly alternates with the small sedentary bud-producing generation. Now as the bud-producing or Polyp generation of the common Jelly-fish referred to is fixed to the bottom, the proximity to a coast, or at any rate to a shallow water area, is a necessity for the continuation of the species. Many of the Jelly-fish are undoubtedly drifted out into the open ocean by the tides, but the larvæ they produce, after swimming about in search of something solid to which they can attach themselves, must at last perish. It is only those larvæ which are

hatched near enough to the shore to be able to reach the bottom during the tenure of their lives, that can continue the generation of these Jelly-fishes.

But even in the open ocean far away from shallow water or a coast line, Jelly-fish, belonging of course to different species from those of the coasts, are found. What is their natural history? How is their life different from that of the Jelly-fish of the shore? Some of them produce larvæ very similar to those described above, but they seek, instead of the rocks or sea-weed, other Jelly-fish and attach themselves to them as parasites.

In other species, however, the "alternation of generations" is entirely lost, and the egg gives rise directly to a free-swimming little Jelly-fish which in time grows to be like its parent in size and shape. In this case the fixed or sessile form in the life-history is, as it were, omitted in order that the animal may lead a life independent of the coast and sea-bottom.

The Jelly-fish, then, present us with an interesting example of a manner in which the life-history of an animal may be modified for or adapted to this surface-swimming habit.

There is also another point of interest about these creatures in this connection. In writing about the Copepods I pointed out the mechanical contrivances they exhibit for keeping themselves afloat, namely, the spines, hairs and oil globules. Jelly-fish have neither spines nor oil globules of the same nature, but still their bodies are very light in the water and in the absence of muscular movements sink but slowly to the bottom. This lightness is due to the fact that

all the tissues and organs of which it is composed are very largely distended with water. When the body of a Jelly-fish is analysed it is found that over 95 per cent. of it consists of water. This power of absorbing large quantities of fluid into the tissues, while it increases the size of the body, proportionately diminishes its weight in water.

It has also another effect. It makes the tissues of the body much more transparent and gives them that soft jelly-like consistency which is so characteristic of the surface-swimming forms.

The popular term 'Jelly-fish' is one that is frequently applied to many forms of surface-swimming animals that are really very different in structure and general composition from the true Medusæ. The Salps, for example, to which reference will be made presently, although soft and transparent in texture like the Medusæ, belong to a very widely separated group of animals, and to the anatomist it would be as absurd to classify them together, as to put the Butterflies and the Fish in the same group.

These remarks are necessary because in the treatment adopted in this little book the animals that live together are considered in the same chapter, and it is important that the reader should bear in mind that they are not as a consequence anatomically related to one another.

It is indeed remarkable that animals which are so different from one another, in their anatomy, development and life history, as, for example, the Salps and the Medusæ, and which have had such a widely different ancestry, should, as a matter of fact, resemble one another so closely in form and texture as to be given col-

lectively the same name by the unscientific observer.

Among the heterogeneous crowd of animals that are popularly called Jelly-fish there is one particular group which presents us with some very interesting members. These are the Siphonophores. In many parts of the temperate and warmer seas of the world the surface may be covered with thousands of little creatures which, when brought upon the deck, seem to be little else than coloured bladders of air. The scientific name of these animals is *Physalia*. When placed in a glass of water, however, it will be seen that, from the under side of the bladder which floats freely on the water, numerous delicate tentacles and Polyps hang down. These creatures are kept at the surface by an air-bladder float and no muscular energy is required to sustain them in that position.

Another Siphonophore called Velella has a bladder of a more complicated character in the shape of a disc with a semicircular or triangular sail on its upper side. There can be no doubt of the advantage of this float to the species. It not only enables them to keep afloat without the expenditure of muscular energy, but as the wind catches the sail they are drifted along over great areas of the ocean and thus distributed far and wide from the spot on which they were hatched. Still the float has undoubtedly its disadvantages, for it ex-

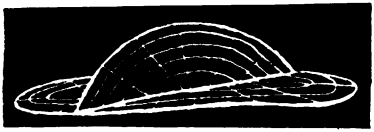


FIG. 26.—The swim-bladder of Velella.

poses them to the danger of being blown ashore by a steady wind and so perishing in thousands. Agassiz says that on the coast of Florida the beach is sometimes marked with lines of Velellas that have been stranded in this manner, and I have seen in Celebes four or five rows of bright blue Physalias stretching for miles along the shore.

In the Mediterranean and Eastern Atlantic Ocean a very large Physalia occurs which has received the popular name of the "Portuguese man-of-war," and is famous for its stinging powers. The stinging is produced by a number of very minute sacs, which shoot out, when they are touched, a long pointed thread that penetrates the skin and conveys an irritant poison. These are called the thread-cells, and the "Portuguese man-of-war" is not by any means peculiar in possessing them. All the Medusæ and Siphonophores, all the true Corals and Sea-anemones have them—in fact, all those creatures which are classified together by the zoologist as *Cœlenterata* may be said to be stinging animals. The thread-cells, however, vary very much in size in this group, and in the great majority of cases the thread is too feeble to perforate the skin of the human hand, and consequently their owners have not acquired a bad reputation.

People do not warn their children not to touch the Sea-anemones on the rocks or the Jelly-fish stranded on the beach, and yet they are both dependent for their food upon their stinging powers; and indeed many of the British Medusæ which may be handled with impunity, are capable of stinging quite severely the more delicate skin of the back and arms of unwary bathers.

Besides the two forms of Siphonophores which have been described, there are many others to be found at or near the surface of the seas of all climes. Some of them possess great floats like Physalia and Velella, but the majority of them have either no floats at all or such as are too small to do more than assist in keeping the animal near the surface. All of these Siphonophores are provided with little bells, which, contracting rhythmically like a Jelly-fish, drag the animal along, sometimes to the surface, sometimes a few fathoms below it. Some of these forms are extremely graceful, being like long strings of jelly, with numerous clusters of Polyps and long feathery tentacles, towed through the water by one or two exquisitely delicate little bells situated at the leading end of the string.

A few words must now be said about the Salps, because in some seas the water is on occasions so full of them that they seem to be packed together ready for preserving. The simplest form of Salp is like a small sac or barrel of transparent gelatinous substance open at both ends. Running round the barrel are five or seven bands of a less transparent nature, appearing to the unaided vision like milky white streaks. These streaks are bands of muscles by which the movement of the body through the water is assisted. Sometimes they are seen swimming about independently of one another, sometimes Salps very similar to them in general appearance are seen to be attached to one another in long chains. At first it was supposed by naturalists that the former or Solitary Salps were of a different species to the latter, or Chain-salps as they are called; but it has been discovered that these two

forms are but stages in the life-history of one species. When the anatomy of a Chain-salp is minutely examined it is found to contain a single egg, which gives rise to a young Salp similar in nearly all details to the solitary one. This escapes from its parent's body when it is old enough to take care of itself, and leads an independent existence. After it has grown to its full size it gives rise to a stalk which divides up into a number of young Salps, attached to one another in a very characteristic manner.

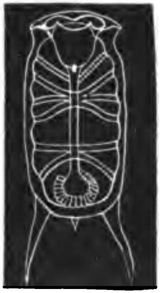


FIG. 27.—Solitary form of Salp, bearing a young stalk of Chain-salps.

Here, then, we have another instance of alternation of generations similar in this respect to the example previously quoted among the Jelly-fish, in that the one generation produces an egg, and the other numerous buds; but differing from it in the fact that in the case of the Salps both generations are adapted for freely swimming at the surface of the sea.

Space does not allow us to say more in detail about the other animals of the Plankton that belong to the same group as the Salps; of the wonderfully interesting life-history of *Doliolum;* of the extraordinary bright light emitted by *Pyrosoma*, or of the remarkable little *Fritillaria*, shaped like a tad-pole, living in its house of jelly. The story of each of these might take a whole chapter to itself and still be only partly told.

Anyone who is acquainted with the general appearance of the Whelks and Periwinkles, and other Gastropods of our shores might be well as-

tonished when he saw, for the first time, many of the Gastropods of the high seas. The shell is either absent altogether or consists of a thin little papery cap far too small to afford protection to the body. The head and foot, and, indeed, the greater part of the body, are transparent, soft and gelatinous like a Jelly-fish, in fact the whole appearance is so different that it is not until the internal anatomy is carefully studied that their true position in the animal kingdom can be assigned to them.

Here, then, we find another instance of a profound modification of structure associated with the surface-swimming habit; the modification being due very largely to the absorption of considerable quantities of water into the tissues of the body, which has the effect of rendering them transparent, and, at the same time, of reducing their weight in the water.

The transparency of the body of so many of the animals of the Plankton has suggested the theory that by rendering them less conspicuous to their enemies it is of the nature of a protection to them. We ought to hesitate before accepting this theory until we know more accurately what are the enemies that they endeavour to protect themselves against. It is very probable that none of the Fish will feed upon any of the transparent Jelly-fish, neither is there any evidence that the Salps and the pelagic Gastropods form a favourite food for them. There is no good reason for supposing that the Sea-birds would, if they could see them better, prey upon them, so long as there are Fish in the sea to provide a more substantial and satisfactory meal. The Whales, as they dash through the water with

their huge mouths wide open, undoubtedly swallow them in thousands, but it can not be reasonably supposed that the Whale can be guided by sight in the selection of its food. We ought not, perhaps, to go so far as to say that it is no protection to them, for Prof. Moseley states that the Turtle sometimes feeds upon the Velellas, but at the same time we may consider that the transparency is an effect produced by the large amount of water in their tissues, which is there for the purpose of reducing their specific gravity and assisting in that manner in their flotation.

The only Gastropod found in the open seas which retains in its characteristic form the large coiled shell, is the beautiful blue *Janthina*, famous for its habit of constructing a little raft which floats on the surface of the sea. To the underside of this it attaches its eggs and spends its life in pushing or dragging the raft about.

Fig. 28.—A Pteropod, showing the so-called wings.

No account of the Molluscs of the Plankton would be complete without some reference to the Pteropods These creatures are provided with a pair of muscular lobes of the body, which have been compared to wings. By means of these they are able to swim through the water. Some of them are provided with delicate little glassy shells, but in others the body is quite naked. We may regard the Pteropods as the most highly

modified forms of Gastropods adapted for a pelagic life.

In both the Arctic and Antarctic seas this group occurs in immense numbers, and it is supposed to form not an inconsiderable proportion of the food of the gigantic Right-whales. They also occur in the Temperate and Tropical zones, and indeed there are actually more genera and species there than in the colder regions to the North and South.

The Insect world is represented at the surface of the ocean by a curious little Bug called *Halobates.* It is not uncommonly found in tropical or subtropical seas feeding upon dead Salps or Jellyfish, and when disturbed scuds over the surface after the manner of many of the Insects living on our inland ponds and lakes. It has been described as an "ivory-legged fellow, covered with a bluish-white down." As it is essentially an air breather like all adult insects, its usual habitat is '*on*' the sea and not *in* it, so that strictly speaking it is not a member of the Plankton. There is no doubt that under certain circumstances it can and does dive into the water, and on these occasions it carries with it for resoiratory purposes a layer of air attached to the bluish-white down' covering the body.

There are no traces of wings on its thorax, and it is therefore incapable of flight. Very little is known at present of its development, and practically nothing of its internal anatomy, so that its proper position in the order of the Bugs or *Hemiptera* is a matter of conjecture, but it is an interesting little creature, in the fact that it is the only member of its class that has a purely pelagic life-history.

Among the microscopic forms of life found in the Plankton of the sea, the Radiolarians and Foraminifers are perhaps the most important. The Radiolarians are very minute specks of protoplasm, usually protected or supported by an elaborate skeleton of a substance closely allied to flint. The form of this skeleton varies so much in the numerous species that have been described, that it is quite impossible in a few words to give an adequate idea of the principal types. (See Fig. 2.) We may say, however, that in a considerable number of them the skeleton has the form of a hollow sphere, perforated by numerous round holes and supporting outside a number of long thin needles. The anatomy of the Radiolarians is extremely simple. Their bodies are built entirely of protoplasm which performs all the vital functions. There is no definite head, mouth, brain, nor muscular organ. This being the case, the question arises, How do these animals provided with a skeleton of such a heavy substance as flint manage to support themselves in the water without muscular appendages? The answer to this question is two-fold—In the first place, the elaborate form of the skeleton presents an enormous surface to the water in proportion to its weight, and consequently sinks slowly; and secondly, the protoplasm is provided with numerous vacuoles containing a watery fluid, and in many cases at least one larger vacuole containing oil. If the liquids in these vacuoles are lighter than sea-water, and there is good reason to suppose that some at least of them are, then they are of the same nature as the oil chambers of the Copepods, and are hydrostatic in function.

Among the Foraminifers very few genera strict-

ly belong to the surface Fauna. Most of them have heavy, compact shells of carbonate of lime, and they live among the sand or the rocks at the bottom of the sea. The best known of the surface-dwelling forms is *Globigerina*, and this, in accordance with its habits, possesses a shell which, like that of the Radiolarians, is very light, perforated by numerous large holes and provided with long delicate spines. The shell of *Globigerina* might well be mistaken for that of a Radiolarian were it not for the fact that it is composed of carbonate of lime instead of flint.

FIG. 29.—Shells of Foraminifers living at the bottom of the sea.

The Radiolarians in some waters, and the *Globigerinidæ* in others, are present in enormous numbers, and as they die their shells fall in a gentle rain from the surface towards the sea-bottom, where they frequently form a very large part of the abysmal mud.

In speaking of the organisms of the surface of the sea no mention has yet been made of the plant world. Of the large conspicuous Sea-weeds that are often found far out in the open ocean the best known is the Sargasso or Gulf-weed of the Atlantic. It forms in some cases great floating patches, of very considerable area, and

is, when alive, of a bright yellow colour. The Sargasso patches are, however, of great interest to the zoologist, because they support a considerable population of animals specially adapted by their form and colour to live among the Sea-

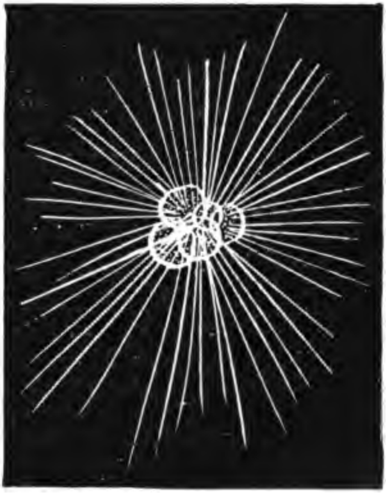


FIG. 30.—Globigerina living at the surface of the sea.

weeds. They present us, in fact, with a peculiar Fauna, containing representatives of all the most important groups of marine animals.

Besides the large conspicuous weeds like the Sargasso, the surface of the sea supports a large Flora of minute plants of very lowly organisation, and it is not at all uncommon for them to be present in such numbers as to cause a distinct discoloration of the water.

The banks that they form on the coast of Brazil and elsewhere were called "Sea-sawdust" by Sir Joseph Banks. Moseley says that "when tracts of the sea are passed through, which are full of this *Trichodesmium*, the water lighted up by sunlight, when looked down into, appears as if full of small particles of mica or some such substance, so strongly is the light reflected from the minute bundles of the Algæ"; and again, he says, "so abundant is *Trichodesmium* in some seas that one of the explanations of the name of the Red Sea is that the term was derived from the discolouration of the water by vast quantities of *Trichodesmium erythræum*."

In addition to this "Sea-sawdust," Diatoms, the still more minute organisms, the Bacteria, and the debatable particles called Coccospheres and Rhabdospheres, add to the number of the floating Flora of the seas.

The importance of these organisms to the zoologist is that they must ultimately form the food supply of the animals of the Plankton. Some of the larger animals may feed upon the smaller ones, and the smaller ones may, in their turn, feed upon still smaller ones, but we must come eventually, in descending the scale, to the animals that are vegetable-feeders and prey upon the minute plants that have just been mentioned.

Now that we have considered very briefly some of the principal forms of life that compose the floating and drifting population of the surface, we may return to the subject with which the chapter opened, namely, the phosphorescence of the sea.

It need hardly be mentioned that it is a subject which is beset by innumerable difficulties.

Even when the sea is extremely phosphorescent, and the observer is provided with an excellent microscope and all the necessary scientific appliances, he finds it difficult to answer the question —"What is the cause of the phosphorescence to-night?" The sample of water he takes may reveal to him a multitude of different organisms, many of which are so small that they can only be seen with a strong artificial light, and then it is impossible to say which are and which are not phosphorescent.

Some of the Copepods are known to possess an organ emitting a bright blue star-like light which shines for a time and is then suddenly extinguished. In the Malay Archipelago several of these bright lights may be seen near the surface of the water on calm mornings just before sunrise, and it is extremely interesting to watch them gradually sinking down into deeper water as the day dawns, and then suddenly going out one after the other.

Some of the large Jelly-fishes, such as *Pelagia noctiluca*, glow with a soft blue light. The curious pelagic Tunicate colony *Pyrosoma* receives its name from the fact that it emits a bright light. A giant *Pyrosoma* was caught by the *Challenger* in the deep-sea trawl, and, to quote the words of Professor Moseley once more, "It was like a great sac, with walls of jelly about an inch in thickness. It was four feet in length and ten inches in diameter. When a Pyrosoma is stimulated by having its surface touched, the phosphorescent light breaks out at first at the spot stimulated, and then spreads over the surface of the colony as the stimulus is transmitted to the surrounding animals. I wrote my name with my

finger on the surface of the giant Pyrosoma as it lay in a tub at night, and the name came out in a few seconds in letters of fire."

All of these animals are sufficiently large to be easily seen by the naked eye, and the phenomena of their phosphorescence can be carefully observed. But many of the more minute forms of life also exhibit this peculiarity, and contribute in no small degree to the bright light of the sea.

For instance, when the sea on our coasts shows a dull blue light, flashing into greater intensity where the ripples break, it will be found to contain immense numbers of very minute creatures called *Noctiluca.* Each of these has a gelatinous consistency, and is the shape of a microscopic cherry, bearing a short whip-like process, called the flagellum, which propels the organism slowly through the water. There seems to be no doubt that, on these occasions, the light is caused by these *Noctilucas*, but there are many other minute forms which abound on the surface and give off a pale phosphorescent light at night.

We do not know for certain what may be the use of the phosphorescent light to the organisms that possess the power of emitting it. If we assume that the transparency of the bodies of the pelagic animals has a protective value in the daylight, it is difficult to understand why many of them should become so attractive, as the phosphorescent light makes them, at night. It is probable that the star-like lights of many of the Copepods may serve to attract to one another the two sexes, as it does with the Glow-worms and Fire-flies, but such an explanation as this cannot well be accepted in the case of *Pyrosoma*, which is hermaphrodite, or the *Noctilucas*, which live to-

gether in immense numbers. There can be little doubt, however, that there is some good reason for it, as it occurs in so many different animals belonging to widely separated families.

In the neighbourhood of coasts or in shallow water, the surface of the sea usually supports a very large number of animals in a larval or immature state. These creatures live only a portion of their lives in a free swimming condition, and then a change occurs during which they sink to the bottom and gradually assume the adult characters.

Nearly everybody is acquainted with the general appearance of the Crab and Star-fish, but few would guess that the young stages of these animals are to be found among the minute transparent floating Fauna of the surface waters of the sea.

The habits of the young and of the old of these animals are widely different; the former must constantly support themselves in the water, they must feed upon and have means for catching and devouring minute floating organisms and must in other ways be adapted for life with the Plankton; the latter being unable to swim are capital crawlers and walkers over the rocks and sand of the bottom, have heavy bodies which sink rapidly in the water and, in other ways, are adapted for life with the shallow-water Benthos.

The conditions of life at the surface and at the bottom being, as I have previously pointed out, so different and the adaptations of structure to suit each set of conditions so great, we have, as a result, a long series of animals in which the young larval stages of life are absolutely unlike the adult and mature stages.

No better examples to illustrate these changes

could be given than those chosen from the group of the Echinoderms. Take, for instance, the common Star-fish with its thick heavy skin studded with plates of carbonate of lime, and its dense opaque body drawn out into five finger-like processes. These features of the animal indicate at once that its life is spent crawling on the sand or rocks at the bottom of the sea. If a Star-fish that has been caught in a lobster pot or brought to the surface attached to the bait on a fishing line, is cast into the sea it sinks to the bottom at once without any apparent effort to swim, to keep afloat, or to arrest its rapid descent. It is therefore clearly unfitted for a surface-swimming existence, but its eggs give rise to larvæ which are admirably adapted to it, and can indeed only exist at or near the surface of the sea. These larvæ are, as a rule, when first hatched, covered with a number of very minute vibratile cilia, by means of which they swim with considerable rapidity through the water. After a time a number of bands appear, which are covered by specially long cilia and then the smaller cilia on the intervals between the bands disappear.

FIG. 31. Young larva of a Star-fish before the Brachiolaria stage is reached.

The precise arrangement of the bands differs in the different species, but from being at first perfectly circular in contour they become more and more curved and twisted, sometimes fusing with one another and in parts degenerating, until, at last, when the larval stage reaches its full development, the bands have assumed an elaborate and somewhat fantastic pattern.

The body of the larva is, like that of so many surface-swimming creatures, extremely transparent. The uniform oval shape which it has when first hatched becomes changed as it develops by the formation of a certain number of short blunt processes or arms, and it was the presence of these which caused the older naturalists to call this larva the Brachiolaria.

If one of these minute Brachiolaria larvæ be caught and examined with a microscope it is not difficult to see that it has a little round mouth leading into a short digestive canal which opens to the exterior by a vent. It is therefore clearly capable of feeding itself and leading a perfectly independent existence. In the older larvæ there will be noticed an appearance which has, under a low magnifying power, the form of an incomplete and rather opaque ring round the stomach. This opaque ring becomes larger and larger, it exhibits five projections radiating from its centre, and at last gives rise to all the organs of the fully formed Star-fish. As the ring develops the larva sinks from the surface and loses the power of independent feeding, and then, when all is ready, the skin is cast off and a small but perfectly formed Star-fish emerges.

The Trepangs, the Brittle-stars, the Sea-urchins and other Echinoderms have, as a general rule, life-histories similar to that of the Star-fish, but there is one point of difference in detail which is of sufficient interest to be mentioned before passing on. The larva of the Brittle-stars and of some of the Sea-urchins has a number of arms which are much longer, in proportion to the whole size of the larva, than they are in the

Brachiolaria, and on account of the manner in which these arms are inclined towards the apex, the larva has a rough resemblance to the form of a painter's easel. This type of larva is called the Pluteus. The main point of interest about the Pluteus, however, is that the arms are supported by delicate bars of carbonate of lime which are connected together at the apex and form a very definite larval skeleton.

This larval skeleton is cast off with the skin when the metamorphosis takes place, and it is consequently of great interest to scientists in the fact that it is one of those structures which is formed to meet the exigencies of larval life only, and is perfectly useless for the adult. In considering the manifold questions which arise in the study of the relation of animals to their surroundings we are often inclined to fix our attention too exclusively upon the adaptations that are manifested in the adult form. In the case of some classes in which the immature stages of life are passed through very rapidly and under the protection of the parents, this is not to be deprecated; but in most cases it is important to remember that in the struggle for existence there is such danger of extermination that each stage of life may have acquired special characters for adaptation to its particular mode of existence. The peculiar markings and colours of the Caterpillars is a familiar example of the special characters of larval forms among terrestrial and air-breathing animals, but in none of these do we

FIG. 32.
Pluteus larva.

find so great a specialisation in larval characters as in some of the marine forms of life.

It is said above that the Echinoderms as a general rule have free-swimming larvæ, but there are exceptional cases which have an interest for us quite as great as that of the ordinary life-history.

Many Echinoderms are found living in very great depths of the ocean and it is difficult for us to believe that any of these can have pelagic larvæ similar to those of their shallow water relatives. The difference in pressure between that of the bottom of the deep sea and of the surface is, by itself, sufficient to convince us that a delicate organism like a Brachiolaria or Pluteus could not make the upward journey unharmed; but when we add to that the great distance of two or even three miles in a direct line, the difference in temperature and in light, we must realise that the ordinary transformations of the shallow water Echinoderms is an impossibility for the deep-sea varieties.

As a matter of fact we know very little about the life-history of deep-sea Echinoderms, and this is not a matter for wonder when the reader reflects upon the great difficulties that have to be overcome in obtaining a few specimens of the adult forms; but at least one of the Star-fish of the Abyss has been found to bear little pouches or pits in which the young are fostered until they are ready to lead an independent life in the form of the parents.

It has also been shown that in some of the Arctic Star-fishes the larval life is in a similar manner abbreviated and protected, and it seems probable that this may be accounted for by the

fact that the surface waters, where the larval forms would live if they were liberated, are for very long periods covered with ice.

The great group of the Crustaceans also presents us with many interesting larval forms specially adapted to surface life. In a previous chapter I have pointed out that the Barnacles of our coast give birth to curious little free-swimming, six-legged larvæ called Nauplii, which after having undergone two or three further changes, settle down on a rock and assume the adult features (see Fig. 12).

It is not known how long these changes take in the ordinary course of nature, but it is quite probable that the larval life is a comparatively short one.

Some Barnacles, however, live far out at sea on drifting wood or parasitic on the skin of Whales, and it is reasonable to suppose that when their larvæ are hatched a very considerable time may elapse before they find a suitable resting-place to complete their metamorphosis.

The life-histories of these species are not at present accurately known, but a few remarkable Nauplii have been found which, there is reason to believe, are really the Nauplii of some kind of Barnacle and are specially adapted to a long life at the surface by the enormous length of their spines.

In the specimen discovered by Chun in the Canary Islands, of which a figure is given here, the spines were seven or eight times the length of the body, the eye was remarkably small, and the muscles were feebly developed. It may be that this is the larva of some species of Barnacle, which, from the character of the host or home

where it lives when adult, must be prepared to wait a long time in its larval habitat before the chance comes for it to find a suitable resting-place.

Many of the Crabs and Prawns have remarkable larvæ, characterised either by two or three extremely long spines or in some cases by a festoon of shorter and many branched spinous processes spreading out from their carapace, tail and limbs. These spines may be regarded partly as a device for assisting in the flotation of

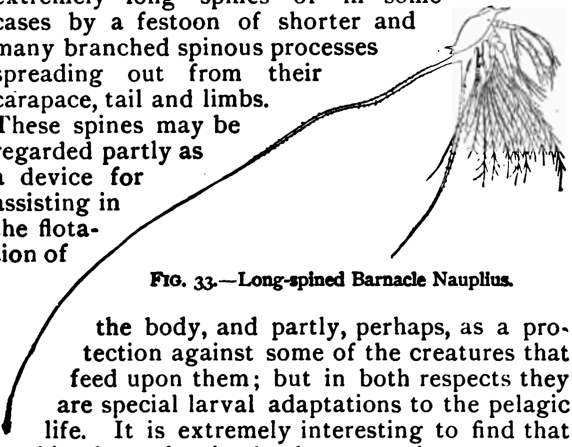


FIG. 33.—Long-spined Barnacle Nauplius.

the body, and partly, perhaps, as a protection against some of the creatures that feed upon them; but in both respects they are special larval adaptations to the pelagic life. It is extremely interesting to find that in this class of animals the same characters are not constant in the larvæ. A Prawn called *Palinurus* has a larva the body of which becomes extremely expanded and flattened, so as to resemble a very thin sheet of glass, the eyes and the limbs at the same time undergoing remarkable modifications. Another larva becomes extraordinarily distended by the absorption of water into its tissues so as to resemble in texture a small Jelly-fish.

A great deal more might be said about the story of Crustacean larvæ, as it is one which is

full of interest and wonder, but throughout the whole of it we see, wherever there is a larval history at all, that some one or more of those characteristic features have been evolved, which were previously noted in adult animals as an adaptation to their free-swimming pelagic life.

In many other groups of marine animals we find the same alternation of a transparent larval life at the surface and an opaque adult life at the bottom.

The Oysters, Clams and Mussels, the Winkles and other Gastropods, the Worms, the Sponges and many other forms of life that creep among the Sea-weeds and are fixed upon the rocks or burrow in the sand, produce exquisite and delicate transparent little larvæ which for a certain length of time at least float and drift about in the light of the sunshine in the surface water. They have, of course, many varieties of form and many peculiar organs for locomotion and flotation, so that it is possible for a competent zoologist to tell without much difficulty the group of animals, if not the actual genus and species, to which any particular larva belongs.

It might be thought that, as so many of the animals living near the coast line in shallow water have pelagic larvæ, the Plankton of the neighbourhood of the coasts would differ from that of the open oceans in the fact that a considerable proportion of it consists of these larval forms. But many of the larvæ seem to be able to live a long time without further change than an increase in size, and being drifted out to sea by the winds and tides are often found in the open ocean at very great distances from any coast line.

It would be interesting to know more of these

larvæ which go thus astray. How long can they go on waiting for the opportunity to cast off their childish clothes and assume the garments of the adult? Do they in time undergo changes which bring about a kind of childish old age, or do they suddenly perish with all the characters of youth upon them?

These and many other questions connected with this most fascinating chapter in the story of the sea have still to be answered by the investigations of scientific men in the future.

CHAPTER V.

SURFACE-SWIMMING FAUNA (VERTEBRATES).

In the preceding chapter we have considered only those animals of the surface of the sea, which, owing either to their small size or the transparency of their bodies, are not as a rule conspicuous to a passenger on board a mail-steamer. Such a passenger might cross the ocean many times without realising in the least the wealth of animal life that there is in every wave that breaks upon the ship, and yet be impressed with what he has seen of the Whales and Porpoises, the Sharks, Bonitos and Flying-fish.

It is to these groups of animals that a few lines must be devoted before closing our story of the surface-swimming Fauna. If the young and immature stages be for the moment left out of consideration, it may be said that nearly all the Fish and all the Whales and Porpoises are large,

opaque in appearance, and perfectly conspicuous. Moreover, they are all strong and rapid swimmers, capable of roaming over wide areas of the sea in search of prey, and independent of, except in so far as their prey are influenced by, the currents and winds. It is clear that they cannot be said to 'float' and 'drift' about in the ocean, and consequently they do not strictly belong to the Plankton. The term used in speaking of them collectively is the Nekton, which means the swimming population.

The greatest number of the Fish of the sea are shore Fish; that is to say, they habitually feed at, or close to, the bottom of the shallow waters near the coast or sunken banks.

But there is a very considerable number that are strictly pelagic, living and feeding far away from the shores, bringing forth their young alive, or shedding floating eggs, and in every way independent of the shore and of the bottom.

It is difficult to give any general features by which they are characterised, as so much variety may be observed among them; but as a general rule they are elongated in form, round or oval in section, in colour green or gray above, with silvery white bellies. Some of these, such as the Flying-fish and the Flying-gurnard, are capable of making very considerable flights in the air, their pectoral fins being enormously elongated, and when fully expanded somewhat similar to the wing of an Insect.

The Flying-fish occur in shoals in nearly all tropical and subtropical seas. When disturbed by a ship on a calm day it is said that they spring out of the sea, expand their fins, describe a regular parabolic curve in the air, and then fall with a

splash into the water. There is a considerable controversy raging on the question of the use of their fins in this flight through the air, some observers believing that the fins are used only as a kind of parachute, and others that they are used like wings for raising the body above the water. It is very difficult to decide which view is correct.

In the Indian Ocean I watched the Flying-fish for several days during rather rough weather, and my impression was most distinctly that in the middle of the flight the fins are vigorously flapped four or five times, the flapping being followed by a decided rise in the air. On the other hand, it may be that this flapping appearance is caused by the wind catching the wings in a certain position, and not by the muscles of the fish. Whether the flying is actually assisted by the flapping of the wings or not, it is certain that the Fish do rise in gusty weather to a very considerable height, frequently falling on the decks of steamers twenty feet above the water line.

At night, these Fish fly at the ships and not away from them, as they do in the day time, and the natives in some parts of the Malay Archipelago catch them in large numbers by holding up a torch by the side of a large sheet, when the Fish flying at the bright light and striking against it, fall into the bottom of the canoe. Flying-fish are excellent to eat, their flesh being similar in taste to that of the Herring, but an epicure would probably say that it is not quite so good.

The Bonito is a fish occurring over a wide area of the tropical and temperate seas, which sometimes makes tremendous jumps out of the water. I have seen it frequently on the coast of Celebes jump to a height which I roughly estimated as at

least fifteen feet. It is said to feed upon the Flying-fish, and it is probable that it has acquired the power of springing out of the water in the pursuit of its prey.

The pelagic Fish, which has acquired the widest reputation, and that an evil one, is the "blue Shark." This occurs in the tropical and occasionally in temperate seas. Its usual size is from twelve to fifteen feet, but, according to Dr. Günther, individuals of twenty-five

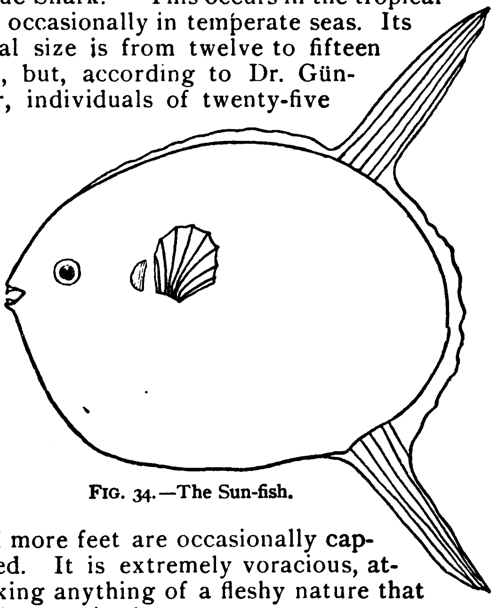


FIG. 34.—The Sun-fish.

and more feet are occasionally captured. It is extremely voracious, attacking anything of a fleshy nature that it observes in the water.

One of the most remarkable animals of the open ocean is the Sun-fish. It has a very wide distribution in the tropical and temperate regions. In the adult condition it is almost circular in outline and considerably flattened from side to side

like a John Dory. It sometimes reaches a size of eight feet in diameter and a very great weight. From the little that is known of its development it apparently undergoes some extraordinary changes in shape before it reaches the adult form.

In addition to these and several other Fish of a large size which may be found at the surface of the open ocean, there are several species known to science which never grow to a length of more than a few inches. Many of these are characterised by remarkably long fin rays, by their large eyes, or by other features which may be regarded as special modifications for their peculiar habits.

A very interesting genus is *Scopelus*, which is found very widely distributed in tropical and other seas. Some of the species live in very deep water, and are purely abysmal in habit, but most of them rise to the surface at night, when they may be caught in immense numbers. In form they are not unlike a small Sprat, but they exhibit on each side of the body a series of minute eye-like organs, which emit a phosphorescent light.

In addition to these Fish, which are found far out in the open ocean, there are several genera, which form an important feature of the surface waters in the neighbourhood of the coasts. Among them we find such valuable food-fish as the Herrings, Sprats, Mackerels, and Pilchards.

The complete history of the Herring has yet to be written, for, notwithstanding the laborious investigations of several naturalists, working independently, or as officers of the Marine Biological Association and similar Institutions, there are some facts and stages which have, up to the present time, escaped observation.

The Herring species is divided into a number

of races, which, differing from one another only slightly in anatomical characters, have different seasons for depositing their eggs. This fact has only recently been thoroughly established; and while it assists us greatly in the task of completing the history of the Fish, it definitely destroys the validity of many theories which were prevalent among fishermen and others before the days of the more exact scientific treatment of fishery questions.

It is well known that from the end of the month of June to December immense shoals of Herrings are found in the North Sea. It is quite impossible to estimate the numbers of Fish in these shoals, but they are so great that if they could be counted it would probably be found that the Fish that are annually caught by all the fishing boats, form but an insignificant fraction of the whole. All of these Fish are in such a condition that it is evident their spawning time is close at hand. When they are ready they approach the coasts, the exact time varying according to the race of Herrings, and the spawn is deposited on or close to the ground, the eggs becoming attached to stones and other objects on the bottom. After the Herrings have spawned, they seem to disperse, or, at any rate, to disappear from the surface-waters of the North Sea. What actually becomes of these shoals of spent Herrings is not known, but it is a fact that in the spring there are so few Herrings to be found in the narrower part of the North Sea that it does not pay the fishing boats to go after them. It is possible, however, that, after the spawning process, the Herrings migrate to the deeper water of the Norwegian coasts, in order to feed on the

Crustaceans and other forms of life that are to be found there in abundance.

The Mackerel do not apparently make such extensive migrations as the Herrings. They spawn in the open sea, five or ten miles from the coast, during the spring time. The egg of the Mackerel, unlike that of the Herring, does not sink to the bottom when it is spawned, but, being provided with a large oil globule, it is light enough to remain on the surface until the young larva is hatched. After the spawning has taken place the Mackerel approach the coast, and will even enter bays and narrow inlets on the shores in pursuit of the young Sprats and other small Fish upon which they prey.

A great deal could be written on the history of the Pilchards, the Anchovies, the Sprats, and other Fish which frequent the surface-waters of the sea in the neighbourhood of the European coasts. No two species seem to have precisely the same habits, and what is known about them presents us with many curious and remarkably interesting facts. For further details, however, I must refer the reader to the larger and more comprehensive books dealing specially with the subject, for space must still be found for a few words on another group of animals which play a conspicuous part in the story of life in the seas.

The animals composing the class of Mammals are distinguished from other Vertebrates by the fact that the females are capable of providing milk for their young ones after birth. Most of the Mammals are strictly terrestrial, but three orders, namely, the *Cetacea*, the *Sirenia*, and the *Carnivora* contribute to the surface-swimming population of the sea.

The *Cetacea* are all aquatic. The order includes the many genera of Whales, Porpoises and Dolphins.

The Right-whales are distinguished by the enormous size of the mouth and the absence of the little triangular fin in the middle of the back which is found in the other Whales.

These animals have no teeth in the adult condition, but are provided with a series of plates situated at the sides of the mouth which are used as strainers to catch the small Pteropods and other animals living in the water which pass through the great gape. The plates are composed of a substance called "Baleen,"—the well-known whale-bone of commerce,—they are triangular in shape, and frayed out into a brush-like edge on the side that faces the cavity of the mouth. The Greenland Right-whale attains to a size of fifty feet in length when fully grown, and it is usually found in shoals among the ice floes of the far north.

In former times many Right-whales belonging to species allied to the Arctic form occurred in the temperate regions of the Atlantic and Pacific Oceans, but in consequence of the valuable fishery they afforded they are now becoming very scarce.

The largest of all the Whales—in fact, the largest existing animal—is the Blue-whale, which attains to the enormous length of 86 feet. It spends the winter in the open seas, and approaches the coast of Norway in the spring.

The Whales, like all the animals of the Class to which they belong, are air-breathers. They are able, however, to hold their breath for a considerable time under water. When they come to the surface to renew the air-supply in their lungs,

they first make a violent expiratory effort from the nostril, and drive a column of spray many feet into the air above them. This phenomenon is called by the whale fishers "spouting," and it was erroneously supposed by them to be a column of water forced from the mouth into the nostril, and then expelled at the surface.

The Dolphins and the Porpoises are distinguished from the true Whales by the fact that they are provided with teeth, on one or both of their jaws, and there is no "whale-bone."

The Sperm-whale has probably been called a "Whale" from its enormous size, but it is anatomically very widely separated from the true Whales and more closely allied to the Dolphins. It has no "whale-bone," and the lower jaw is provided with a row of sharp-pointed teeth set in a groove in the bone. Its great value is due to the fact that there is a large cavity situated above the skull, containing an oily substance from which "Spermaceti" is made.

The principal food of these large "Toothed-whales" seems to be Cuttlefishes, and the examination of the contents of their stomachs, which has been carried out on board the Prince of Monaco's private steam-ship when engaged on a scientific cruise, has yielded some new forms of these giant Molluscs. The Sperm-whales, however, do not disdain a Fish diet as well.

The Porpoises are found on our own coasts. They may often be seen following the "schools" of Whales as they approach the coast in the summer months, and they occasionally chase their prey some distance up the estuaries of the English rivers. The habit that Porpoises have of accompanying ships for long distances affords us many

opportunities of watching their graceful movements, and of estimating the very great speed with which they can swim through the water for hours at a stretch. It is difficult to understand the meaning of this habit of following ships. It has been suggested that the Porpoises mistake the ship for a huge Sperm-whale, and hope to benefit by stray morsels of large fish that fall from its jaws. But this theory does not account for the fact that the Porpoises so often go in front of the ship. The following extract from Darwin's "Voyage of the Beagle" gives, in a few words, a vivid picture of Porpoise life:—

"In our passage to the Plata, we saw nothing in particular, excepting on one day a great shoal of Porpoises, many hundreds in number. The whole sea was in places furrowed by them; and a most extraordinary spectacle was presented, as hundreds, proceeding together by jumps, in which their whole bodies were exposed, thus cut the water. When the ship was running nine knots an hour, these animals could cross and recross the bows with the greatest ease, and then dash away right ahead." This description reminds me very forcibly of a sight I once saw in the Talaut Islands, south of the Philippines. In passing between two of the islands the strait seemed to be alive with Porpoises tearing through the water at a terrific pace. They accompanied the steamer for about six hours and then suddenly disappeared. My impression was that they were attracted to the ship not from a desire for more food, for there was an abundance of Herrings in the straits at the time, but from sheer curiosity. I think the feeling of curiosity, that is to say, the desire to go and look at something strange or

unusual, is much more prevalent among animals than we generally suspect.

It is an interesting fact about the Porpoise that, although it is so fish-like in shape, it should present some features which remind us of the Pig. The English word is probably derived from the two French words *porc* and *poisson*, and therefore means "Pig-fish." The Germans call it Meeresschwein, meaning "Sea-pig," and the Malay word for it is "Babi-laut," which also

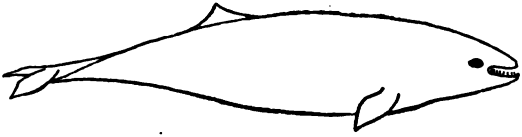


FIG. 35.—The common Porpoise.

means "Sea-pig." But if we make some allowance for those who call these Cetaceans "Pigs," we must make none for those who call them "Fish."

Like all the other members of their order the Porpoises have a fish-like tail, but the flaps are placed horizontally and not vertically as they are in Fish. The skin is quite naked, having no scales of any kind, and there are no gills or gill-openings. Like all other Mammals the Cetaceans bring forth their young alive, suckle them, and breathe air by means of lungs. But there can be no doubt that they are extremely modified for their aquatic life. The characteristic covering of Mammals—the hairs—is, in the adult condition of the Whales, entirely wanting, and is represented in other members of the Class by only a few bristles on the snout. The heat of the body is

maintained by a thick coat of fat, called the blubber, lying immediately beneath the skin, and this yields, on boiling, a valuable oil, which helps to support the whale-fishermen. One of the most striking modifications, however, is the loss of the hind limbs. It is only in some species that even rudiments of these have been found. All of these facts indicate that the Cetaceans must have taken to a mode of life in the water a very long time ago, and the study of the rocks proves the existence of Whales as far back as Eocene times, but it is of interest to note that, in some respects, the oldest fossil Cetaceans are less specialised than those that are now living.

The class of Mammals called the *Carnivora* includes the Cats, Dogs, Ferrets and many other animals which are purely terrestrial, but one of its divisions is entirely composed of those well-known aquatic animals the Seals and the Walrus. If we take the common Seal as an example of this group, and compare it with the Porpoise, as a representative of the Cetaceans, we find that in habits as well as in anatomy the former is less completely changed than the latter. The Seal frequently comes to land to bask in the sun, or to produce and care for its young, and it is capable of making some progress over the rocks by the help of its flipper-like fore-limbs; the Porpoise, on the other hand, never leaves the water of its own free will. Unlike the Porpoise the body of the Seal is covered with a thick coat of hairs, and the hind limbs are retained. Although there is a general resemblance in the form of the body between these two animals—this form being, in all probability, mechanically the best for rapid progress through the water—a glance

at their skeletons shows great and important differences, which the merest tyro in anatomy could point out. In expression, too, there is a marked difference, for while the Porpoise has a certain cast of countenance which, when seen at a distance, deserves the epithet "pig-faced," the face of the Seal, with its large round eyes, its small nose and high intelligent brow, is almost human in expression.

The Seal has a habit of raising its head above the water and staring at an approaching boat, and when doing this it may readily be mistaken at first sight for a man overboard, but no one could ever mistake a Porpoise for a human being.

The common Seal has a very wide range occurring near the coast of both the Atlantic and Pacific Oceans. It is found on some of the more sequestered parts of the British shores, but not in large numbers, for the common Seal, unlike many of its allies, does not appear to congregate in large shoals at any time of the year. They are described as being timid, inoffensive creatures, easily tamed, passionately fond of their children and taking an intelligent interest in music.

There are several animals closely related to the Seal, occurring in different parts of the world; and a few words may be said about the remarkable animal called the "Sea-elephant," which is found on Kerguelen island in the Antarctic Ocean. The popular name was given to the animal in consequence of the fleshy protuberant nose which has been compared with the trunk of an Elephant and is possessed only by the male. The late Professor Moseley, who came across a small herd of them when the *Challenger* was at Kerguelen, says: "The trunk is produced by an inflation of a loose

tubular sac of skin placed above the nostrils, just as the 'Cap' in the northern Bladder-nose Seal. The trunk is evidently, as appears from both the drawings, sacculated, and hence irregular in form when inflated."

The Sea-lions and Sea-bears or the Eared Seals, as they are sometimes called, form a very distinct family. The one that is best known to the general public is the Californian Sea-lion, as it often lives in captivity in the European menageries for many years and attracts the attention of the visitors by the tricks which it is taught to perform.

In the spring months of the year these creatures may be seen in great numbers on the rocky islands of the coast of California, where they come to breed.

The most important of them all, from a commercial point of view, is the Fur-seal from the Northern Pacific. In the month of May these animals approach the Pribylov islands in the East, or the Commander islands in the West of the Behring Sea. The first to arrive on the land are the old males. These choose for themselves certain areas or 'homes' on the shore and fight desperately for their possession with all who dare to come within their reach. When matters are at length somewhat settled the time arrives for the females to approach the shore. The fighting then begins again with renewed vigour, and desperate encounters take place for the possession of a goodly stock of wives for the season.

There seems to be little in the way of courtship in the domestic economy of the Fur-seals, the wives being simply "captured" by the scruff of their necks when they come within reach of a

would-be husband, and retained in his harem just so long as he can prevent any one of his neighbours from stealing her. The Fur-seal, like all his relations, is polygamous, but the number of wives that each male appropriates to himself seems to vary very considerably. Mr. Elliott mentions a case in which there were as many as forty-five females in one home, but, as a general rule, the number is much less. As there is only one male to every twelve or thirteen females, there are numerous males over, which cannot found a home for themselves. These bachelors, together with a number of the young females, resort to a separate piece of ground, where they spend their time in playing games. The playgrounds are however the scene of the tragedies of Seal life, for they are resorted to by the hunters, who slaughter immense numbers of the larger males for the sake of their valuable skins. As the skins of the old male Seals are not of very much value and as it is important, for the perpetuation of the race, to preserve the females from injury, the breeding grounds are usually not molested. It is therefore the bachelor seal of from two to five or six years of age that has to supply the market. Those naturalists who have visited the Seal rookeries on these islands say that the numbers of these animals that can be seen at one time is almost incredible. We can form some estimate of them when we learn that over a hundred thousand skins are exported from the Pribylov islands alone every year.

The Seals leave the rookeries in the month of August, and after swimming about for some time in the neighbourhood of the islands, eventually depart into the open ocean in search of the food

their famished bodies need so much after the fasting and fighting of the breeding months.

The largest of all these aquatic Carnivores is the Walrus, which lives within a short distance of the shores of the lands in the Arctic regions. It is easily distinguished from the Seals by its great size, the males reaching a length of 10 or 12 feet, and by the enormous canine teeth in the upper jaws, which project downwards from the cover of the lips in the form of two large pointed tusks. These tusks are used for hoisting the bodies of the animals on to the ice, for digging in the sand in search of the Mussels upon which they feed, and for general fighting purposes.

It is said that in former times the Walruses lived in immense herds in regions much further south than they do now; but the ravages of the hunter, who chased them for their ivory tusks and their oil, have driven them into regions where they are rarely visited by anyone but the Arctic explorer; and to those of my readers who wish to learn more of their habits, I can but say that in the pages of Dr. Nansen's book, "Farthest North," he will find the story of the Walrus written in a manner which no man living could have done more vividly and brilliantly than the great Norwegian zoologist and explorer. (*See Frontispiece.*)

CHAPTER VI.

DEEP-SEA FAUNA.

SOME of the most important conditions under which life at the bottom of the deep sea occurs have been mentioned in the first chapter. We have pointed out that the pressure is enormous, that the temperature is only a few degrees above the freezing point, and that, except in those places where phosphorescent animals emit a faint light, it is absolutely dark, no rays of direct sunlight being able to penetrate such a mass of water as lies between the bottom of the ocean and its surface.

With such conditions to contend with it is not surprising that the naturalists at the beginning of the century believed that no animals could possibly live on the floor of the great oceans. Their beliefs, however, merely afford us an example of the danger of prophesying without knowing, for the great expeditions which have investigated the ocean bed during the last thirty years have proved the existence of a rich and peculiar Fauna in all the great depths that have been dredged. The general results of these investigations have been recently summed up by Dr. John Murray in the last volume of the *Challenger* Reports. He points out the extraordinary variety of life in the deep sea as shown by the contents of the dredge. "At Station 146 in the Southern Ocean, at a depth of 1375 fathoms, the 200 specimens captured belonged to 59 genera and 78 species." He

can find no record of species equal to this in depths of under 50 fathoms, and concludes that the evidence at present before us is sufficient to warrant the belief that the great depths of the ocean are as a general rule extremely rich in species.

From what has been already said, it may be gathered that nearly all the most important groups of marine animals have representatives in the deep sea. There are Fish, Tunicates, Crustaceans, Molluscs, Echinoderms, Worms, Cœlenterates and Protozoa. Nearly all of these are so modified, either in form or colour, or the structure of their organs of sense, or in other particulars, that they could be recognised at once in a collection as deep-sea animals; but there is a small minority which seem to have undergone but little change in adapting themselves to their strange environment.

We may commence our study of this remarkable Fauna by a few remarks on their colour. The first and most striking feature is that the animals are almost invariably uniform in colour. If they are dark-brown they are dark-brown all over, if they are red they rarely exhibit bands of white or spots of blue. Moreover, they are not always in harmony with the colour of their surroundings.

In the shallow waters the animals that live among the green Sea-weeds are green, those that live on the sand are coloured like the sand, and many of those that live among the rocks are darkly pigmented with black and blue. In the abyss of the ocean, where there is any light at all, the colour is, in all probability, fairly uniform over wide tracts, and yet we may find in one haul

of the dredge, black Fish, red Crustaceans, and purple Trepangs.

There seems to be no particularly predominant colour among the deep-sea animals. Most of the Fish are black or dark brown, but many are light violet, some are pale rose and others bright red. Among the Crustaceans bright red seems to be the prevailing shade, just as the darker tints of black and brown are among the Fish.

Among the Echinoderms we find white, purple, yellow, red, and pink forms, and among the Jelly-fish and Corals, red, violet, and green. In fact it would be necessary to describe every class of animals in turn, and then almost every genus in each class, to give an adequate idea of the variety of colour met with in the Fauna of the deep sea.

It is inconceivable that each of these animals can live amid surroundings of a colour similar to its own, and therefore we may without much hesitation believe, that the colour of deep-sea animals is not, as a general rule, of use as a protection.

Next to the peculiarities of colour, the most striking features of the more highly organised inhabitants of the bottom of the sea are the modifications of the organs of special sense. The Fish, the Crustaceans and the Molluscs almost invariably exhibit some remarkable modifications of the eyes. In their natural haunts there must be either absolute darkness, or the faint and usually intermittent light emitted by phosphorescent animals. How intense this light may be it is impossible to judge. The light that is emitted by animals on the deck of a ship can afford no criterion of the light they emit under a pressure of

two tons to the square inch. However, the fact that the deep-sea animals have either very large eyes or no eyes at all, suggests forcibly that this light is not sufficient to cause a general illumination.

Some of the Fish are quite blind, and although most of these have a very small and rudimentary eye, in at least one Fish, *Ipnops*, which is peculiar to deep water, no trace of an eye is to be found.

In some genera with a very wide distribution, a very interesting series of stages may be found, indicating the changes that may have taken place in the history of the blind Fish of the abyss. In the genus of deep-sea Cods (*Macrurus*), for example, those species which live in water of less than a thousand fathoms depth have very large eyes, and those that are found in greater depths have much smaller ones.

The same in general is true of the Crustaceans. The deep-sea Cray-fish have lost not only their eyes, but also the stalks which supported them. In *Bathynomus* (a Crustacean belonging to the group *Isopoda*), however, there is a pair of enormous eyes. But as a rule the eyes of Crustaceans degenerate and disappear in shallower water than the eyes of Fishes. At depths of 500 fathoms or greater, the eyes of the Crustaceans usually show signs of reduction in size or other retrogressive changes, and in the greatest depths they are nearly always wanting altogether.

Accompanying the loss of eyesight in deep-sea animals we often find a very remarkable development of organs, which may be regarded as especially tactile in function.

Many of the deep-sea Fish, for example, with rudimentary eyes possess long barbels, and in

some cases the paired fins are enormously elongated to form delicate pointed organs like the tentacles of a Polyp. Among the blind Crustaceans, too, we often find enormously long antennæ, and even the claws and legs are so long and delicate that they bring to mind the appendages of a Daddy-long-legs or a Harvest spider.

Just as a blind man acquires a remarkably acute sense of touch, so, it seems, in the course of generations, these blind animals of the abyss have acquired extremely delicate tactile organs.

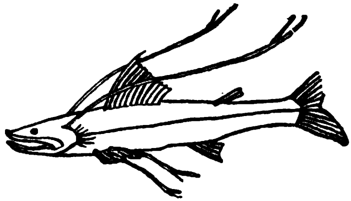


FIG. 36.—A deep-sea Fish showing very elongated fins.

The deep-sea Fauna is also remarkable for the great number of animals which are phosphorescent. As in the surface-swimming creatures, the phosphorescence is not confined to a few classes, but probably occurs to a greater or less extent in all the more important groups. The word "probably" must be used in the previous sentence, because it is not yet scientifically proved that many forms which are supposed to be phosphorescent are actually so; but the evidence is conclusive that phosphorescence is a common and widespread character of most of the deep sea Fauna.

The Fish exhibit, perhaps more than any other group, peculiar organs which are supposed, and in many cases proved to be, used for the purpose of generating light. In the *Stomiatidæ*, a

family of Fish related to the Salmons, there are often numerous little organs, like minute bull's-eye lanterns, arranged in rows on the sides of the body from the head to the tail, and in addition to these in some species one or more pairs of larger organs are seen in the upper lip just in front of or below the large eyes. It is not certain what the colour of the light is that is emitted by these organs, but it is very probable that if the Fish could be seen in their natural haunts they would have an extremely beautiful effect.

In describing the general characters of the shallow-water Fauna in Chapter II. reference has been made to the remarkable lure at the end of the tentacle of the Angler-fish. In the Angler of the great depths this is also found, but in the obscurity of their surroundings a lure, such as that of the shore species, would be useless, and it is actually replaced by an organ which is supposed to be phosphorescent. The mouth is enormous and armed with ferocious-looking teeth, the body is rounded and adapted for burrowing in the ooze, and we can well frame in our minds a picture of the little Fishes and other creatures attracted by the "will-o'-the-wisp" light, meeting with a sudden death in the cavernous jaws of this voracious deep-sea Fish.

It is possible that in addition to the light given off by definite organs, the slime secreted by the skin either over the whole surface or certain circumscribed regions, may be phosphorescent, but how far this may serve as a means of illumination must remain a matter of conjecture. The Crustaceans are in some cases known to emit a phosphorescent fluid. The naturalists of H.M.S. *In-*

vestigator found a brilliantly phosphorescent liquid in the glands at the base of the antennæ and elsewhere in certain deep-sea Shrimps, and one of the Cray-fish from great depths is said to have two definite spots on the body that emit a phosphorescent light.

Several of the Star-fish and Brittle-stars from the abyss are known to be brilliantly phosphorescent, and there are some vivid accounts of the light given off by Worms and various kinds of deep-sea Polyps found in the dredge.

It is possible that some of the more minute forms of life that occur on the mud at the bottom may also be phosphorescent. The *Phæodaria*, a family of Radiolarians peculiar to deep water, provided with thick heavy shells, have a curious organ in their bodies which may be capable of emitting light. If this is the case, it is not unreasonable to suppose that the vast tracts on the bed of the ocean may be faintly luminous like the surface of the sea on a calm night.

Among the other characters must be mentioned a very prevalent deficiency in the salts contained in the skeletons of these animals. The skin of the Fish is usually soft and velvety to the touch, the scales being either very thin and few in number or altogether missing; the bones are described as being so soft that it is easy to pass a needle through them. The shells of the Crustaceans, although frequently drawn out into numerous long and pointed spines, are usually deficient in carbonate of lime. The shells of the Molluscs are, when compared with those that live in shallower water, thin and brittle. The Corals do not seem in this respect to show much variation from their shallow-water relations.

Some of the solitary forms seem to have rather thinner shells, but the colonial genera have, as a rule, as good a support of carbonate of lime in the abyss as elsewhere.

Before proceeding to the next character, it is necessary to digress a little to consider the food of the animals in the abyss. In the absence of any direct sun-light there can be no vegetable growth, all of the animals must therefore be carnivorous. The food must be either the living bodies of the truly abysmal animals, or the dead bodies of those that fall from the surface waters.

It is probable that the bodies of Fish and the larger Invertebrates only rarely reach the bottom, as they have to run the gantlet of many different forms of life living within 100 fathoms of the surface. When, therefore, such a prize does fall to the luck of a deep-sea Fish, it is important that it should have accommodation for it before the neighbours come to share the meal. This may be the cause of the fact that deep-sea Fish have, as a general rule, jaws and stomach that are extravagantly large, even for a carnivorous creature. The width of the gape and the extensibility of the stomach reach their highest grade in some of the deep-sea Eels, which have been found containing Fish actually larger than themselves. In these cases the stomach and the body wall hang down from the under side of the Eel's body in the form of an enormous membranous sac containing the prey.

We have now considered very briefly some of the principal modifications of structure exhibited by the animals of the deep sea, but before leaving the subject altogether it is necessary to refer to

a few of the more characteristic and remarkable forms.

Although it may be considered to be one of the greatest scientific triumphs of the century to have discovered the existence of animal life in a region which nearly all the distinguished men of science of the last generation believed to be as lifeless as the moon, the revelations of the dredge brought with them a certain amount of disappointment.

The study of the crust of the earth has revealed to us the fact that in times long since gone by, there existed not only the hairy Mammoths, the Iguanodons, and many other terrestrial monsters; but that the sea was peopled with certain Reptiles, Fish, Molluscs, Echinoderms, and Crustaceans, which are now believed to be extinct.

When it was first discovered that some forms of animal life had attached themselves to a telegraph cable lying in 1200 fathoms, and that it was therefore a fact that life existed in very deep water, a successful application was made by scientific men to the British Government to assist them in a thorough survey of this hitherto unknown field of investigation.

The result of the voyages of H.M.S. *Lightning* and H.M.S. *Porcupine* was to prove the existence in water of 1000 fathoms in depth of a rich Fauna of rare and very remarkable animals. Among them were several new genera of Sea-lilies and a very curious Heart-urchin. The Sea-lilies that were then known to live in shallow water were very few in number, and nearly all of them were free and unattached. Now, in past times in the history of the earth different genera and species of stalked Crinoids or Sea-lilies were very plenti-

ful, and from their abundance in certain geological deposits, it is believed that they lived in enormous numbers. The discovery of the new genera of stalked Crinoids in the abyss suggested that possibly there might be found several other families of extinct animals still surviving in the deep sea. This view was supported by the Heart-urchin, whose shell showed some striking peculiarities that were only known in fossil genera.

But the hopes that were felt, even if they were not always expressed, were doomed to disappointment. No living Ichthyosauruses or Plesiosauruses, none of the remarkable Ganoid fish of Devonian times, no Trilobites, no Cystoids nor Blastoids,—in fact none of the most interesting of the fossil types rewarded the investigators of the *Challenger* and subsequent expeditions.

It is perfectly clear to us now that, taken as a whole, the deep sea Fauna is not more ancient in character than any other Fauna. It is true that a few genera, such as those just referred to, have survived, probably from very ancient times, without much modification; but the vast majority of forms are simply shallow-water animals, which have been profoundly modified in structure, and adapted to the peculiar conditions of existence in the great depths of the ocean.

CHAPTER VII.

COMMENSALISM AND PARASITISM.

THE term Symbiosis has been applied by naturalists to the phenomenon of the living together for mutual help or protection of different species of animals or plants. It is a well-known fact, to all those who have taken an interest in any large group of animals, that some species are nearly always associated with other species, belonging perhaps to a different class altogether, and very frequently mimicking them in form or colour. At first it might be thought that most of these cases could be dismissed as cases of parasitism; but when the careful observer notices that neither of the species is injured by the association, the conditions of the partnership are evidently very different to those of a blood-sucking parasite and its ungracious host.

Besides the words Symbiosis and Parasitism, the terms Commensalism and Mutualism have been applied to various cases of association of different species of animals; but with the increase of our knowledge of the habits of animals, it is becoming more and more difficult to classify all known cases under these four heads, and the words are consequently often used with widely different meanings.

It will be perhaps the best plan to adopt in this book, to avoid any attempt to give definitions of these terms until a few cases illustrative of each have been described.

One of the commonest objects of the sea-shore is the Hermit-crab. From the open mouth of what is apparently an empty shell a bundle of claws and legs may be seen to protrude: turn the shell over and it will scamper away into the deeper parts of a rock pool. This is an association of a living Crab with the shell of an animal that is dead; but if the Hermit-crab be extracted it will be seen that it has a soft and twisted tail, quite unlike that of the shore Crabs, and that it could not possibly live for any length of time without the shelter and protection afforded by the shell that it has appropriated to itself. The Hermit-crab in the course of its life increases in size, and when it gets too big for the shell it is living in, it goes in search of another a little bit larger and changes, until at last it attains to the size and dignity that requires a full-grown Whelk shell.

In the waters of the coast just beyond the low tide mark we often find that the shell containing a Hermit-crab bears a Sea-anemone which belongs to a species rarely found anywhere excepting in association with a Hermit-crab. Moreover, the Anemone is always seated in a definite position on the shell, so that its mouth is turned towards the jaws of the Hermit-crab when it is extended, enabling it to catch any morsels of food that escape the mouth of its comrade. When the Hermit-crab has grown too large for its shell, and moves into a new one, the Anemone moves too, and takes up the same position on the new shell that it occupied on the old one, and the companionship is continued in this manner throughout life.

The advantage of this arrangement to the Anemone is obvious, for it can not only obtain

its food after the manner of the other Anemones, but it also gains a share of the food of the Hermit-crab. The advantage to the Crab is not so apparent, but it is probable that the Anemone, being very distasteful to many Fish and other animals, acts as a protector to it. The facts that Hermit-crabs are extremely shy, darting back into their shells when there is the slightest sign of danger, and that they are extremely good bait for many kinds of Fish, suggest very forcibly that they have many enemies among the inhabitants of the deep. Any such covering as that afforded by the Anemone, which hides to a great extent the character of the shell, would be of protective value, but when to that is added the fact that the Anemone, which affords this covering, is avoided as uneatable and distasteful by carnivorous Fish, there can be no doubt whatever of the assistance that it renders to the Crab in return for its board. If any of my readers are sceptical about the distastefulness of Sea-anemones I would ask them to think of any instance in which Sea-anemones are used for bait, and then to try the experiment of offering pieces of them to the Fish in an aquarium.

An observation by Prof. Möbius in the Indian Ocean affords another example of the use of Sea-anemones in this respect. He discovered a little Crab called *Melia tesselata* which carried about in each of its claws a Sea-anemone. When the Crab was alarmed it held them up in much the same way that a man holds a torch, as if it would call attention to the fact that it had these terrible weapons at hand. When the Anemones were removed it carefully searched for them, and held them up again when found, and even when the

Anemone was cut into pieces the Crab diligently collected them, arranged them as far as possible in their proper places, and held them up together.

But Sea-anemones are not the only animals that seem to be generally distasteful to Fish. Many of the Sponges are free from attack, and could serve as a protection to the Hermit-crabs. On British coasts a small brown Sponge is not infrequently brought up in the dredge surround-

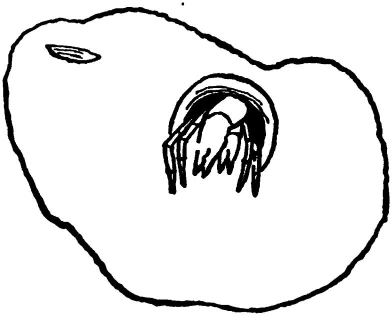


FIG. 37.—Hermit-crab protruding from its hole in the sponge.

ing and protecting a Hermit-crab; and hidden somewhere in the substance of the Sponge, there may always be found a small shell which lies at the end of the hole in which the Crab lives.

This association is, from the Crab's point of view, a more advantageous one than that with the Sea-anemone, for it does away with the necessity of any changes of shell, the Crab and the Sponge growing up together. The history of the companionship is probably as follows:—A small Hermit-crab takes for its shelter a small Gastropod shell, and upon this shell a Sponge larva settles,

grows and spreads, until it surrounds the whole of it except the hole from which the Crab emerges. As the Sponge grows still further in thickness the margin overlapping the aperture of the shell expands, leaving a conical cavity leading from the exterior to the shell, surrounded, of course, by Sponge structure, in which the Crab lives. Thus as the Hermit-crab increases in size it is ever provided with a wider hole to accommodate its body by the growth of the Sponge, and the little shell wholly deserted remains as a token of the past history of the pair. But in the later stages of growth a third creature is taken into the partnership, in the person of a small segmented Worm which lives in the hole with the Hermit-crab. The need for this third person seems to be one of a sanitary character. The cleanliness of the Hermit-crab, which has no sponge to protect it, is provided for by the simple expedient of frequent changes into a new home. In this case it is arranged for by taking into the home, on what we may call board wages, an efficient scavenger.

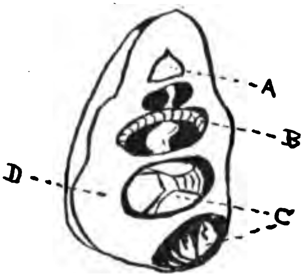


FIG. 38.—Section through a sponge (*D*) showing the little shell, *A*; the worm, *B*; the Hermit-crabs in their natural positions, *C*.

In this remarkable association, then, no less than four species belonging to four different groups of animals are concerned. First of all there is the *Gastropod* Mollusc, which forms a shell for the *Crustacean* Hermit-crab to commence

life in, then there is the *Sponge* which protects, and afterwards forms a shelter and home for the Hermit-crab, and lastly, there is the *Annelid* worm, which helps in its way to keep the house clean in return for the scraps of food that fall from the head partner's table.

A very similar association has recently been described by Bouvier from the Gulf of Aden and Red Sea waters. A number of simple solitary Corals were thrown into an aquarium by a French naturalist, some falling on their sides and some on their crowns, but he noticed that, after the lapse of some time, they were all in the erect position again with their crowns of tentacles expanded in the water. On carefully watching them he observed that at the base of each Coral there was a little hole from which emerged a small unsegmented Worm, belonging to a family that usually exhibits sand-burrowing propensities. These Worms were found to be the agents which restored the Corals to their erect positions. The advantage of this arrangement to the Worm was two-fold: it brought it into direct contact with the sand in which it searches for its food, and, at the same time, it brought the Coral into such a position as to hide and protect it from its enemies above in a most effectual manner. To the Coral it was obviously an advantage, in that it placed it in a position to expand its tentacles in search of the food it seeks in the water and prevented a death from suffocation. A more minute investigation of the Coral, however, revealed the fact that hidden in its substance there was a small Gastropod shell on which we may suppose both the Coral larva and the Worm settled when the partnership began, and that in association

with the Worm there was a small bivalve Mollusc which probably acts as a scavenger in the manner of the Worm in the last-mentioned case. Here again, then, there are three different species living together to their mutual advantage and commencing their association on the shell of a fourth species belonging to a different class of animals. What words can we apply to these associations? The Hermit-crab and the Anemone feed at "the same table" and therefore they afford a case of "Commensalism"; the Coral and the Worm are of advantage to one another, the former in shielding and protecting the latter and the latter in keeping the former in an upright position, but as they do not feed "at the same table" it is not a case of "Commensalism" but rather one of "Mutualism."

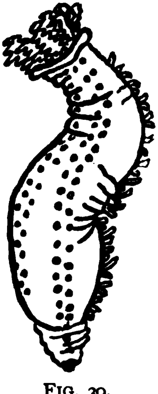


FIG. 39.
A Trepang, or Sea-cucumber.

There are many cases, however, of the association of animals in which, although the advantage to one of the partners is clear, it is extremely difficult to say what benefit is derived by the other.

Living in a tube on the coast is a very common Worm called Sabella, and at the mouth of the tube a little Polyp may frequently be found which has received the fanciful name of the "Household god of the Sabellids" (*Lar Sabellarum*). The Polyp undoubtedly benefits by the currents of water which the Worm sets up when feeding, but it is difficult to see what advantage, if any, the Worm gains from the presence of the Polyp.

Again, some of the Trepangs are frequently inhabited by a little Fish called *Fierasfer*, which comes out from time to time to feed and "take the air," but rapidly retreats into the body of the Trepang on the slightest alarm.

The large stinging Sea-anemones of the Coral often afford protection of a similar kind to a little Fish. Saville Kent gives a beautiful picture of a little bright-red Fish swimming about on the disc of a large purple Sea-anemone, and he says that it darts into the mouth when alarmed. On our own coasts we may often observe a number of little Fish generally belonging to the Cod-family swimming round the disc and tentacles of the large Jelly-fishes, and these, when frightened, swim vigorously toward the under surface of the umbrella and seek security there. Sometimes as many as a hundred or more of them may be seen hovering round one large Jelly-fish, and we can hardly estimate how valuable to our sea fisheries is the protection afforded by these great Medusæ to the young Fish fry.

It was not my purpose in writing this book to point out the practical value of scientific investigation, but this history of the Jelly-fish and Codling cannot be passed without comment. The Jelly-fish might readily be regarded by the ignorant not only as useless to man, but, in so far as they sometimes choke his fishing nets and sting his hands and arms, a positive nuisance to him. Scientific investigation when pursued by properly qualified persons for its own sake, and not for any definite commercial results that may possibly come out of it, frequently reveals facts of the utmost importance, such as the one that has just been mentioned.

There are some other cases of association which would on first consideration be called undoubtedly cases of parasitism, but as this term has been used somewhat vaguely in popular English, it would be well, before proceeding further, to place before the reader a definite statement of the sense in which the word is used in this book.

In many of the cases that we have mentioned hitherto of animals living together, no apparent injury is inflicted upon either of the associates, but a very definite and decided advantage accrues to each of them, by the association.

In other cases, however, whilst no apparent injury is inflicted on either, the advantage of the partnership falls entirely to one of them.

In a third set of cases one of the associates feeds upon the blood or tissues of the other without rendering it any service in return, and consequently inflicts either temporary or permanent injury. These are cases of parasitism. In such an association the animal that inflicts the injury is called the "parasite," and the one that receives it, the "host."

One difficulty the naturalist has to contend with in trying to use these terms correctly is that of finding out whether in any particular case an injury is inflicted or not; another is that of determining whether those animals should be called parasites which injure, alter, or destroy the tissues of their hosts without feeding upon them.

A few cases will throw more light upon the subject than any further discussion of the difficulties surrounding the application of these terms.

One of the commonest Corals to be found upon the coral-reefs of both the Old and New

World is one called *Millepora*. In the Millepores of the Pacific region we very frequently find a number of Barnacles (called *Pyrgoma milleporæ*) so deeply buried in the substance of the Coral that their presence is indicated only by a small oval hole on the surface. There can be little doubt that in the course of the growth of these Barnacles they distort, if they do not actually destroy, some of the connecting canals of the Coral in their immediate neighbourhood, but their food is derived entirely from the water that surrounds the Coral and not any portion of it from the cells or tissues of the Coral-polyps themselves.

There is a great deal of difference in the Millepores from one and the same coral-reef, in the extent to which the Barnacles have attacked them. In some specimens large areas of the Coral are beset with the little holes, in others only one or two may be found on the whole colony, whilst others again are quite free from them. Now when we compare carefully the anatomy of those Millepores with the Barnacles and those without them, no single sign or symptom can be found that the vigour or strength of the former is in any way impaired. If then there is no evidence that the Barnacles are parasitic, in the sense that they are injurious to the Millepores, we must next inquire whether they could possibly be of any service to them.

The polyps of the Millepores feed after the manner of the polyps of other Corals, upon minute organisms floating in the sea; these they paralyse and capture by means of tentacles bearing stinging cells. The food is in the ordinary course brought within reach of the tentacles by

the tides that sweep over the reefs. The Barnacles also feed upon minute organisms of the same kind, but they are provided with six pairs of long feathery legs which by a curious vibratory movement create currents in the water. When there are many Barnacles in close proximity to one another it is quite probable that the water is considerably disturbed by these currents, and the constant and rapid flow of fresh water bearing food-organisms benefits not only the Barnacles, but also the Millepore polyps in their neighbourhood.

Thus the Barnacles *may* be a benefit to the Millepores in which they live. It cannot be asserted, however, that this probability is a proved fact. A great deal more knowledge about the rate of growth of the Corals which are and are not affected, must be acquired before such an assertion could be made: but the *probability* that the Barnacles may be of service is sufficient to cause us to hesitate before branding them with the epithet of "parasites."

This particular case, which has been given above in some detail, may be regarded, in a sense, as a test case, because other animals besides the Barnacles, which gain their food by producing currents, are found in Corals. Such are the tubicolous Worms, bivalve Molluscs, and certain Sponges. So plentiful are these on the older branches of some Corals, that quite a rich Fauna belonging to several groups of animals may be found by carefully studying them. These might all be dismissed as parasites by the non-inquisitive mind, but many of them, at any rate, may be regarded by the more cautious naturalist as not injurious, and others perhaps as positively bene-

ficial to the Coral on which they live. There is a very curious case of symbiosis mentioned by Semper, which may be related here as similar in some respects to those above quoted.

On the shores of the Philippine Islands and in other parts of the Pacific Ocean there is a very common Coral named *Seriatopora*. It is composed of numerous delicate branches, terminating in fine pointed extremities, forming hemispherical shrub-like masses, six or eight inches in diameter. Semper noticed that on some of the branches of these Corals there were little heart-shaped swellings, which had the appearance of malformations or structures corresponding to the galls on the leaves and branches of trees. Each of these swellings contained a cavity, communicating with the exterior by two minute holes, in which there was imprisoned a small Crab.

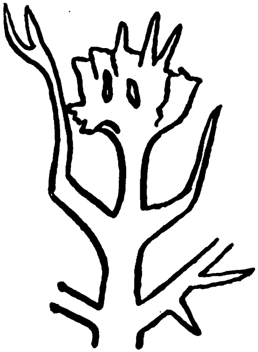


FIG. 40.—A Crab-gall on a branch of a Seriatopora.

By the examination of a large number of specimens, Semper came to the conclusion that the history of these structures was somewhat as follows. The young Crab, when it settled down on the branch, produced an irritation which in some way caused a gall-like growth of the tissues of the Coral. This growth continued until it formed at first a case or sheath for the protection of the Crab, and eventually, as the Crab increased

in size, a cage from which it could not do more than protrude its tentacles and claws when feeding.

It seems very improbable that these cage-like swellings upon the branch can be of any great disadvantage to the Coral. It is true that they destroy the beautiful symmetry of the branch, and give it a distorted and diseased appearance; but this is only an æsthetic disadvantage, which does not probably count for much in the struggle for existence on the Coral-reef. To the Crab the arrangement is undoubtedly an advantage, as it gives it a secure position, free from the attack of its ordinary foes, where food is probably abundant and easily obtained.

The skin of Whales is often beset with Barnacles; in fact some species of them are found nowhere else but on these Mammals. They are usually deeply embedded in the skin, only a small round hole through which the legs can be protruded, communicating with the exterior. These Barnacles do not feed upon the tissues and juices of the Whale, but, in the usual manner of the non-parasitic Barnacles, upon organisms that swim freely in the water. The advantage to the Barnacles is obvious, as the movements of the Whale through the water must bring them in reach of constant fresh supplies of food, but the benefit to the Whale is not so clear. It cannot be supposed for a moment that the Barnacles assist the Whales in their search for food, nor can they be regarded, when present in great numbers, as a protection to the skin by the strength afforded by their thick calcareous shells; at the same time there is no reason to suppose that their presence is an inconvenience or in any way harmful to the Whales.

These cases of animals bearing on their bodies other creatures which are not in the strictest sense of the word parasites, are but instances of a phenomenon that is very widely spread among marine organisms. There are many cases, however, in which plants and inorganic foreign bodies play a very important part in the economy of animals.

In our chapter on the free-swimming organisms of the ocean, mention has been made of the delicate and beautiful creatures called Radiolarians. Many years ago it was discovered that each of these animals bears in its protoplasm a number of little cells, which from their colour received the name of "the yellow cells." It was clear from observation and experiment that they were neither organs nor products of the Radiolarian, but independent organisms belonging to the Vegetable Kingdom.

More recently cells similar to these have been found in many of the Corals, in Worms, and other animals, and there can be no doubt now that when present they perform very important physiological functions which materially assist their host in its growth and development.

So numerous are these "yellow cells" in some Polyps and so important must be their influence on their vital processes, that it may be confidently asserted that the Polyps could not continue to exist for long without them. In the genus *Millepora*, for example, no single specimen and no single fragment of a specimen that I have examined was devoid of them; and although the numbers vary considerably the most superficial canals of this Coral may in all cases be described as crowded with "yellow cells." But as the "yel-

low cells" are certainly of great physiological importance to the Millepore, it is equally certain that the secretions and the protection afforded by the Millepore are of extreme importance to the "yellow cells." In fact it is not going too far to say that the Millepore and its "yellow cells" are dependent upon one another for their existence, and the naturalist might say with a great deal of truth that this particular Coral is not, strictly speaking, animal in nature, but rather an animal and vegetable combination.

Many years ago there was a bitter controversy among learned men on the question of the animal or vegetable nature of Corals. The great naturalist Linnæus, who was appealed to for his support by both parties to the controversy, took up a middle position, asserting that they were partly of the nature of animals and partly of the nature of plants, and hence the term "zoophytes," *i. e.* animal-plants, came to be applied to them There can be no doubt that in the end the position in the controversy, assumed by Linnæus, became untenable, and the supporters of the animal view of zoophytes won all along the line. It is curious, therefore, that we are now in a position, not to support the view of Linnæus, but to assert that some Corals are essentially a combination of animals and plants.

Plants are of use to marine animals, however, in another manner. Mention has already been made of the way in which many animals resembling in colour, and even in form, certain kinds of sea-weeds, escape the attention of their enemies and hide for safety among the plants they simulate. Sometimes, however, the weeds will grow upon the shells of the animals, and thus hide

them even more effectually. One of the most remarkable instances occurs in a Spider-crab that is common upon British coasts. The *Inachus*, as it is called, is usually covered with a little forest of algæ, which do not grow there naturally, but are actually placed on the carapace by the Crab itself. If the plants be scraped off artificially the Crab will go in search of fresh ones, carefully chew the bases until they are soft, and then deliberately decorate the carapace with them as before.

There are some Molluscs that artificially decorate themselves with little shells and other objects in such a manner as to completely hide their general form. One of the most remarkable instances of this occurs in the Gastropod *Xenophora*, which covers its own shell with numbers of others belonging to a smaller species, so that in the natural state it has the appearance of a conglomerate of shells. The manner in which the smaller shells are fixed has not yet been described, but from the orderly arrangement which they exhibit in some cases there can be little doubt that they are deliberately placed in position by the Gastropod itself and not attached by accidental contact.

In both these cases it is clear that the reason for the phenomena described is that of affording a covering or mantle, which hides or obscures the real form and character of the living animals.

Many of the Worms use little bits of shell and grains of sand to build up a tube for the protection of their bodies. One of these—the *Terebella*—is common on British shores, the sandy tubes ending in a tuft of fine filaments, and decorated all over with tiny little stones or shells, projecting

an inch or two from the surface of the sand. In some localities these tubes may be found in thousands when the tide is low.

Another form—*Pectinaria*—constructs much firmer tubes, which retain their cylindrical shape after the death of the animal. In the process of construction this Worm must carefully select the grains of sand, for when the tube is examined with a magnifying glass the particles will be seen to be of almost exactly the same size, and arranged in their places with a mathematical precision.

But Worms are not by any means the only animals that use the sand in this manner for the protection of their bodies. There are some kinds of Polyps, belonging to the family *Zoanthidæ*, a peculiar group of Sea-anemones, in which the body-wall is considerably strengthened by foreign bodies of various kinds. The *Zoanthus* does not, like the Terebella-worm, form a tube or case in which the body can freely move up or down, but sticks the grains of sand into its skin, so that they become in the older forms deeply buried in the tissues and give a considerable support to the body-wall.

The *Cerianthus*—another Sea-anemone—forms a tube which is partly composed of a matted network of stinging threads, and partly of the mud in which the animal lives.

The use of foreign inorganic substances for the protection or concealment of animals is not, strictly speaking, however, a part of the subject-matter of this chapter, which was intended for the consideration of the associations of two different kinds of living organisms.

The subject of Parasitism must now be con-

sidered, a subject which presents so many features of interest that it is possible here only to touch on a few points of general importance. It is a well-known truism to say that Parasitism, whether in human society or in animal life, leads to degeneration; but there are degrees of parasitism among animals, and consequently degrees of degeneration exhibited by animal parasites. We may roughly divide them into two classes, the outside or skin parasites and the internal parasites, the latter being invariably far more modified in structure and in development than the former.

Among the terrestrial animals we find a great number of external parasites, such as the Fleas and the Bugs, which are only slightly modified, as in the loss of their wings, owing to their habits, and can live an active, if not a very prosperous, life for some length of time apart from the society of their hosts. There are others, such as the Mosquitoes, Ticks, and Leeches, which are only occasional parasites; that is to say, they will suck the blood of another animal when the opportunity is presented, but failing that, are able to continue their life and their race independently. It is not surprising, however, that the terrestrial Vertebrates should be thus subjected to the attacks of these parasites, as their feathery or hairy skin affords a shelter and a foothold, from which the efforts of their hosts to dislodge them are exercised in vain.

The skin of Fish, although covered with overlapping scales, is smooth and slippery, and with the rapid movement through the water many of the forms of parasites of the types we meet on land would, if they existed in the sea at all, find

a difficulty in securing an attachment. It is, however, provided with another means of defence against skin parasites, in the possession of numerous mucous glands which keep the body bathed with a slimy fluid.

Everyone must have noticed the slime that exudes from freshly killed Fish, and if the finger be pressed along the skin it is possible to see the openings of the glands as the slime is squeezed out. In the majority of Fish the openings of the glands are most easily seen on the jaws and the flap of the gill cover.

We must remember that the sea is in most places teeming with the larvæ of Worms, Barnacles and Zoophytes, and the spores of Algæ and Fungi of various kinds. Logs of wood, the iron supports of piers, and the bottoms of ships become covered with various fixed forms of animal and vegetable life when submerged in the sea-water for even a few weeks. How is it, then, that the bodies of the Fish are usually so clean and wholesome? The answer to this question is probably to be found in the slime which, passing continuously over the skin, removes the larvæ and the spores before they can secure a firm attachment.

The Crabs, Lobsters and other Crustaceans free themselves from their skin parasites at every moult, but in some of the large, old Lobsters and Crabs that are caught a considerable number of Worms, Barnacles and weeds are frequently found firmly fixed to the carapace and claws. The Limpets and Winkles of our rock pools are often covered with a little forest of Algæ.

The shells of other Molluscs are, however, kept remarkably clean, and the method by which

they destroy the spores, etc., that settle upon them is not yet fully understood.

One of the most serious of the external parasites is the Hag-fish. This remarkable animal is eel-like in shape, although very different indeed, anatomically, from all the true Fishes, and buries its head in the skin of the Cod and other Fishes as it feeds upon their flesh. In some cases the whole body of the Hag gets inside the host, and it thus becomes an internal parasite. It causes an immense destruction of valuable food fish in some districts.

Closely related to the Hag is the marine Lamprey, which fastens itself to Salmon by its suctorial mouth, causing considerable wounds. This parasite sometimes reaches to a length of two feet, and is often carried many miles up the river by the host to which it is attached.

Most of the Leeches occur either in fresh-water or in damp forests and marshy places. There is one, however, named *Pontobdella*, which is found only in sea-water. It is difficult to give an exact statement as to its size, because, like all its relations, it is capable of very extensive movements of expansion and contraction, but the *Pontobdella* is large for a Leech, and when moderately contracted it may be two or three inches in length. The body of this Leech is covered with small tubercles, and it has a large round sucker at each end. Its favourite hosts are the Sharks and Rays, but as it usually drops back into the water when these Fish are hoisted on to the deck it is not very commonly seen in the fishermen's boats.

The most common external parasites of Fish are the Fish-lice. Most of these are little Crus-

taceans, belonging to a group which includes the Wood-louse. They have curiously flattened bodies, provided with short, bent legs, terminating in sharp hooks, by which they adhere to the body of the Fish and crawl about over the skin. Some of these parasites seem to prefer the tongue as a resting-place, the genus *Glossobius*, for example, being found in this position on the Flying-fish of both the Pacific and Atlantic Oceans. In *Glossobius* we find a very remarkable difference in size and form between the males and females, a condition of affairs which is of very common occurrence among the parasitic Crustaceans. The male in this particular case is so small that it is entirely concealed beneath the tail of the female. In another genus a still more interesting condition has been observed, the small young forms which are males growing up, and changing in later life into females.

There is a remarkable parasite called *Sacculina* which may sometimes be found on the under side of the tail in Crabs. In shape it is like a small pea or bean, and is attached to its host by a number of root-like processes, which penetrate through the skin and burrow deeply into the subjacent tissues. It would be quite impossible to tell to what group of animals this parasite belongs by the study of the adult form alone. It is, in fact, little more than a skin full of eggs. When the development of the eggs is watched, however, it is observed that the young *Sacculina* as it is hatched is very much like the Nauplius larva of a Barnacle. The later stages of the development prove that whatever may happen to the adult the *Sacculina* must be related to the group of the Cirripedia. Later on it is found

that the females settle down on a Crab, lose all their limbs and other Cirripedian characters, and finally degenerate into a mere palpitating sac of eggs.

The males never pass beyond the second stage of development known as the Cypris stage. Several of them may usually be found attached to the female, and although they always remain extremely minute they do not lose entirely their Crustacean features.

For those who are in search of parasites, however, there is no more fruitful ground than the gills. That these organs should be a good place for attack is not surprising, when we consider that to maintain the respiration of the animal a constant flow of sea-water over them must be kept up, and this must bring with it many larval forms which may take the opportunity to attach themselves as they pass through the meshes of the gill filaments. Moreover, it is in the gills particularly that the blood current comes into closest contact with the water, and it requires but a little puncture on the part of the young parasite to reach a constant supply of this nourishing fluid.

It is in the gill chambers that we find most frequently representatives of that interesting group of animals, the parasitic Copepods.

It would be difficult to recognise them as Copepods if we were to judge by their adult characters alone. Unlike the brisk, brightly coloured creatures with long rowing antennæ that we have described above as living a free life in the surface waters of the ocean, these parasites have a white sac-like body, with short blunt processes representing the legs, no eye, and generally

two long thread-like bags of eggs attached to the sides of the rudimentary tail. As we found in the case of the *Sacculina*, the true zoological position of these parasites can only be determined by reference to their developmental history.

In the gill chamber of the Prawns we find a very much modified parasite, which is closely allied to those skin parasites of Fishes mentioned above. Many of my readers may have noticed that in some Prawns there is a wart-like swelling on one side of the neck. If the skin be removed it will be observed that this is in reality a cup-shaped protrusion on the wall of the gill-chamber covering a little, flat, soft animal. In past times it was thought that this was a young flat fish, and a wonderful story of its development was fabricated on the strength of this error. It is now known to be one of these extremely degenerate Isopod parasites called *Bopyrus*.

FIG. 41. A parasitic Copepod.

It is a curious fact that there is very rarely indeed more than one of these parasites on a single Prawn. If there is one in the right gill-chamber there are none in the left, and *vice versâ*. It is difficult to find a satisfactory explanation for this, for it is not at all probable that, during the lives of the many hundreds of forms that have been examined, only one larva has passed through the gill-chamber of each individual. The explanation must be looked for in some hitherto unknown influence which the parasite has upon the constitution of the host, rendering it unsuitable for the attachment of another *Bopyrus* of the same habits.

The case is by no means unique. There are several instances of Fish and other animals that bear one, and never more than one, parasite of a particular species.

A few words must now be added about the internal parasites of marine animals. The subject is really an immensely wide one; for the intestines, body cavities, and even blood-vessels of Fish are liable to the attacks of many different forms of Flukes, Tape-worms, and other kinds of parasites which are not even known by name, perhaps fortunately, to the general public.

The life-history of some Flukes that occur in terrestrial animals has been satisfactorily worked out, and we know that, in most cases, they must infest two different hosts before they can reach maturity. The first of these hosts is usually an Invertebrate, and the second a Vertebrate animal. Moreover, it is known that the larvæ are extremely particular in their choice of the first host, attacking one species, and one species only, of Snail or Slug, or whatever Invertebrate its first host may be. If the first host dies a natural death or is swallowed by any other animal than the parasite's proper second host, it—that is to say, the parasite—dies. It seems probable that the Flukes that infest the intestines of marine animals pass through some similar life-history, but owing to the great difficulties that confront the observer their development has not yet been thoroughly investigated. Similarly the life-histories of the Tape-worms, with which a very large number of marine animals are infested, are not yet known to us. It is comforting to know, after looking through the volumes of papers on these internal parasites of marine animals, that none of them

have been shown to be, even occasionally, parasitic upon man, and we can continue our Fish diet without any misgivings on that score. An exception must, however, be made to this statement for the semi-marine Salmon and Sturgeon, which are suspected of being the first hosts of a human Tape-worm.

It is perhaps unsatisfactory to dismiss the internal parasites of marine animals with so few words, but I feel compelled to do so, not only because I have nearly outrun the limits of space, but because we possess so little positive information on the subject, which is of greatest interest to us here, of their developmental history. Lists of species infesting different Fish and Whales could be published, a statement of the points of anatomical importance which distinguish the families could be written, but they would present few features of interest to the general reader.

It may be well to point out before the chapter is closed, however, that there is probably no branch of our subject that is so little known and presents such a wide and important field for future investigation than the life-histories of these marine parasites.

CHAPTER VIII.

THE ORIGIN OF THE MARINE FAUNA.

When we survey the distribution of living organisms over the surface of the globe, we cannot fail to be impressed with the enormous range in the characters of the physical conditions which are capable of supporting animal and vegetable

life. Thus we find Birds flying in the sunlight of the cold and very light atmosphere of the mountain tops, and Fishes swimming in the chill darkness of the depths of the ocean, supporting a pressure of two tons to every square inch of their bodies. We find Algæ, which give the snow sometimes the name of "Red snow," flourishing at temperatures below the freezing point of water, and we meet with Insect larvæ swimming freely in the water of the hot springs. Some sea-water animals can only be induced to live in the aquarium when the water is kept as pure as it is in the open sea, and languish and die as soon as any impurity occurs; on the other hand, several of the Crustaceans seem to flourish best in stinking and putrescent pools. The desert, the forest, the swamp, the lake, the river, as well as the surface and the bottom of the sea have each their characteristic set of animals and plants modified in structure and form to support life in their natural habitats.

There can be no doubt that at the time when animals and plants first made their appearance upon the earth, their distribution was far more limited than it is now, and that all the adaptations to life in special and extraordinary conditions have been acquired in the course of evolution by organisms which originally existed in one particular zone of the earth.

The reasons which have led scientific men to this opinion are manifold, but not the least important of them are those based upon the presence of organs or rudiments of organs of animals of the present time, which could only have been called into existence at a period when their ancestors had an altogether different habit of life.

For example, in the Birds and Reptiles, as well

as in the Mammals, the presence of openings in the throat during the early stages of development, similar in their position, in their blood-vessels and in other respects to the openings of the gills in Fishes, indicates that their ancestors in remote periods lived in water and not on dry land.

Again the presence of rudimentary eyes in the Mole and other subterranean animals indicates that at one time its ancestors must have lived in the light of the day. The characters of the embryos of some of the land and fresh-water Snails proves that they are derived from ancestors that lived in the sea.

When we collect together all the evidence of this kind and place it side by side with the facts revealed to us by Geology, the irresistible conclusion is arrived at that all animals are originally derived from ancestors that lived in the sea. And when we consult the botanists and find that they are agreed that all plants must have had a marine origin also, the case for the sea being the original home of living organisms may be said to be completed.

It is difficult to picture to ourselves the condition of the earth in those very distant times, when the dry land bore no forests nor grass, the air supported no Birds nor Butterflies, and in the rivers and lakes swam no Fish nor Frogs. It must have been "dry" land indeed, when there were no trees to attract the rain clouds and no herbs or mosses to retain the moisture on the ground. The rivers must have risen and fallen with great rapidity as they carried away the rain that fell in cloud-bursts on the mountain tops.

But speculation on the character of the land in those times is not within the scope of this work,

and we must turn again to the sea to inquire where the primordial animals and plants lived in the days of a lifeless land.

We have seen that in the sea there are three possible habitats for animals and two for plants. The surface waters of the great oceans bear a characteristic population of animals and plants, the bottom of the sea supports a considerable number of animals but no plants, and lastly the shallow waters exhibit an immense variety of Sea-weeds, Fish, Worms, and other creatures. Which of these three was the original cradle of the great classes of animals and plants?

The early discovery of certain animals in very deep water which are closely allied to, if not identical with, some fossils of early geological strata, suggested the idea that a very primordial set of creatures might be found at the bottom of the sea when it was more thoroughly investigated; but, as I have pointed out in a previous chapter, the hope of those who anticipated the discovery of a rich Fauna of "living fossils" were doomed to disappointment.

It is not probable, however, that the abyss of the oceans could have been the cradle of life, even if it had shown a more ancient Fauna than it actually does.

We cannot tell in what form life first appeared upon the earth. Whether the unstable living substance called Protoplasm was in the earliest conditions of the globe formed spontaneously by the chance combination of its elements, or whether some germ or other made a hazardous journey through space from another planet enwrapped in the casing of a meteorite, are questions upon which no light has yet been

thrown by scientific observation or speculation; but this can be said, that at a very early period in the history of life upon the earth the simple green plants must have played an important part. It is on the substances that are formed by the activity of this green coloured substance that all plants and animals are directly or indirectly dependent for their food in the present-day economy of Nature, and we are forced to believe that, whatever may have been the form of the earliest living things, Chlorophyll—the green coloured substance of plants—must have had an extremely ancient origin.

Now, in the darkness of the ocean depths Chlorophyll does not and cannot exist; for it is one of its characteristic features that it is active only in the rays of direct sunlight; and, therefore, it is extremely improbable that the cradle of the marine Fauna could have been there. We are then left with two alternatives. It must have been either at the bottom of the shallow waters or on the surface of the seas.

Both of these sites have had their advocates, but the balance of opinion has now turned decidedly in favour of the first of them—the shallow waters. It is not easy to explain the reasons for this view without assuming a fairly complete knowledge on the part of the reader of the various forms of life that are found in the sea, but still a few words of explanation may be written to indicate that the view is a reasonable one.

In the first place we find, when we take a general survey of the animals that live in the surface water, that they are all specially modified in some way or another in structure or develop-

ment in adaptation to the peculiar conditions of their life. The long spines of the Foraminifers and the Crustacean larvæ, the air bladders of the Portuguese man-of-war, the oil drops of the Copepods, the raft of the Mollusc *Janthina* are, as we have seen, among the characters which distinguish this peculiar Fauna. Now, when we compare these surface-dwelling forms with their nearest relations in the shallow waters, the conclusion we come to is that these features have been acquired by the ancestors of the former, which may have been similar in some respects to those now living in shallow water.

Some of the Gastropods of the shore-waters have a simple cup-shaped shell like that of the common Limpet, but the great majority of them have a shell that is twisted up into a spiral form. This twisting of the shell is, of course, due to the twisting of the mantle or fold of skin which secretes the calcium carbonate of which the shell is mainly composed; and, when we study the internal anatomy of the animal we find that the shape of the mantle is associated with a loss of the organs of one side of the body. To put a long story into a few words, we may say that the Gastropods with twisted shells are lop-sided. Now when we examine the shells of the Gastropods that live in the surface waters of the ocean we notice that their shells are (with a few exceptions such as *Janthina*) perfectly symmetrical, and we might jump to the conclusion that this was due to a corresponding symmetry of the internal organs.

Such a conclusion would, however, be an erroneous one, for the results of the careful anatomical study of these Molluscs proves most

definitely, that although a false symmetry of the organs is often shown, there is a general suppression of the organs of one side of the body. A study of the development of these animals also shows, that in the early stages of their life, the shell is not symmetrical like that of the adult, but twisted into a spiral like that of a Whelk or a Periwinkle. These facts indicate that the surface-swimming Molluscs have passed through a stage in their evolution when their bodies were twisted up into a spiral shell, and that the false symmetry, which they exhibit in the adult condition, is an adaptation to their peculiar habits of life. The study of the group of Gastropods alone then does not give us any evidence in favour of the view that the surface-swimming Fauna is primitive; in fact, it proves almost conclusively that its share in the Fauna has been contributed from the shallow-water districts.

The group of the Tunicates affords similar evidence. There is no good reason for believing that the Salps and *Pyrosoma* which drift about in the surface waters are more primitive than the fixed Sea-squirts of the rocks and Sea-weeds; in fact, the view is gaining ground, as our knowledge increases, that all the free Tunicates must have passed through a sessile ancestry. The evidence afforded by the Cœlenterates is not so potent. Several naturalists believe that some free-swimming form of Jelly-fish was the ancestor, and that the fixed Zoophyte was a stage introduced into the life-history at a later period in the evolution of the group. Others believe that the Zoophyte-stage came first and that the Jelly-fish was introduced, for the pur-

pose of distributing over a wide area the eggs of the species. My own researches lead me to incline towards the latter view, but I feel that it is still far from being proved.

A great deal more could be written upon this fascinating speculation about the origin of Life in the Sea. But it is still a speculation, and all that can be done at present is to weigh the evidence carefully and see in which way the scale seems to point. If I have succeeded in making clear to the general reader the nature of the evidence we can use in judging this question, and have indicated to him the direction in which it seems to *me* to point, my task has been accomplished.

INDEX.

(8)

THE END.